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EIGHTEENTH ANNUAL MEETING.

PAPERS READ.

(IV.)

THE CALORIFIC POWER OF COAL GAS.*

By Mr. F. W. HARTLEY.

The calorific power of coal gas has often been brought under the attention of the Association at its meetings, and various statements of practical working results given; but no record is to be found in the proceedings, of the manner in which the heating power is calculated from the composition; and although this information is to be obtained from scientific books, I have ventured to think that it ought to find a place in the records of our transactions, which form text-books of reference, and the more especially so as of late years many very startling assertions have been promulgated respecting the power of gas for heating purposes.

At the outset, however, we enconnter a difficulty in the fact that very few complete analyses of coal gas have been published, the only ones which I can find and rely upon in relation to London gas being those of Dr. Frankland, made in 1851, and those made by Mr. T. S. Humpidge, of the College of Chemistry, in 1876. The analyses of these gentlemen, as given in the tables annexed, show that London gas differed in no very important degree in 1876 from its composition in 1851, except that from some cause the gas of 1876 contained an unduly large percentage of nitrogen.

TABLE I.

	Dr. Frankland. (1851.)	Mr. Humpidge. (1876.)
Hydrogen	48·70	49·33
Marsh gas	38·20	37·00
Condensable hydrocarbons ($C_n H_m$)	3·45	4·00
Carbonic oxide	7·92	4·97
Carbonic acid	0·30	0·00
Nitrogen	1·00	4·40
Oxygen	0·43	0·30
	100·00	100·00

Two methods have been practised for calculating the heating power of coal gas from its composition—one, and an erroneous one, based upon the elementary composition of the combustible gases (*i.e.*, upon the respective weights of hydrogen and carbon contained in them); and the other, and correct method, based upon the actual volume or weight of the several combustible gases which are contained in coal gas. I say "correct" method, although it is quite open to doubt whether a mixture of combustible gases, such as hydrogen, marsh gas, olefines, and carbonic oxide, do not give a higher calorific effect than is represented by the sum which results from the addition of their several respective powers. In the next place, the hydrocarbons condensed by fuming sulphuric acid are several in number, but are estimated as equal only to olefiant in heating power. It is true that the volume of these is not great, and the volume of olefiant containing an equivalent of carbon to that of the condensable hydrocarbons is calculated from "carbon density."

The method of calculating the heat-power of coal gas from the carbon and hydrogen is altogether wrong, because it leaves out of account the amount of heat which has already been expended in effecting the combination of the elements. The heating power of coals is of necessity, from want of knowledge of their proximate constitution, calculated in this erroneous way; that is, upon the basis of ultimate or elementary composition. Professor Galloway says upon this point: "We are entirely ignorant as regards the density of carbon as it exists in coal. We cannot, therefore, know its proper calorific value; it is possible that its density is different in different varieties of coal. Still less do we know the proper calorific value of the hydrogen in coal; it can scarcely be the same when existing as a constituent of a solid body as when it exists in its *free gaseous* state. . . . From the experiments made on the calorific power of substances, it is known that the calorific power is, in general, less than the calorific power of its elements in their uncombined state. . . . As we neither know how the elements are combined, nor their state of condensation in coal, the results obtained in calculating calorific intensity from its elementary composition can at best be only approximations to the truth." The hydrogen, marsh gas (CH_4), carbonic oxide, and the illuminating gases (represented by the formula $C_n H_m$, as their composition is not found), are the combustibles; nitrogen, oxygen, carbonic acid, and water vapour being, under usual conditions, absorbers or abstractors of heat. Water vapour is not given in the analyses, but is of necessity always present in small proportion in coal gas as supplied for common use.

I deem it needful to make clear what is meant by "carbon density," and how the equivalent of olefiant is deduced from the results of an analysis of coal gas. A sample of gas, after being freed from carbonic acid and oxygen (the percentage volumes of these two gases being at the same time ascertained), is exploded with oxygen, when water and carbonic acid result. The volume of the latter is found by absorption. Another sample of the same gas is freed especially from carbonic acid and oxygen. It is then treated with fuming sulphuric acid, which condenses the gases represented by $C_n H_m$. The percentage volume, or loss, is observed. The residual gas is then exploded with oxygen, and, as before, water and carbonic acid are produced; but the latter less in volume than with the first sample. Deducting the volume of carbonic acid resulting from the second experiment from the volume realized in the first, the difference, after due calculation for the volume of carbonic oxide, represents the carbonic acid due to the combustion of the hydrocarbon gases $C_n H_m$, and the "carbon density" of those gases. Thus, let A represent the CO_2 of the first experiment, B of the second, and C the volume of $C_n H_m$ condensed by sulphuric acid, then $A - B \div C =$ carbon density, or the quantity of CO_2 produced from a unit volume of the light-yielding gases.

In order to find the volume of olefiant which would contain a weight of carbon equal to that contained in a unit volume of $C_n H_m$, we have to take into account the fact that CO_2 contains in a given bulk—say, one cubic foot—only half as much carbon as is contained in a cubic foot of olefiant which is $C_2 H_4$. Hence the volume of CO_2 produced by the combustion of $C_n H_m$ is multiplied by half the volume of the latter; or, what is the same thing, the percentage volume of

* The weights and gravities of the various gases referred to in this paper are based upon the old standard temperature and pressure—viz., 60° Fahr. and 30 in. bar.; these being most familiar to the majority of gas engineers.

$C_n H_m$ found by condensation is multiplied by half the volume of CO_2 produced by combustion.

The average carbon density, or CO_2, produced from a unit volume of the condensed hydrocarbons in the samples of gases analyzed by Dr. Frankland was 4, and in the samples analyzed by Mr. Humpidge 3·5. Multiplying the percentage volumes by half these, we have—

$C_n H_m$ 3·45 × 2·00 = 6·9 $C_2 H_4$ (Frankland).
$C_n H_m$ 4·00 × 1·75 = 7·0 $C_2 H_4$ (Humpidge).

Substituting these figures for the $C_n H_m$ in the previous tables, we have—

TABLE II.

	Frankland.	Humpidge.
Hydrogen	48·70	49·33
Marsh gas	38·20	37·00
Olefiant	6·90	7·00
Carbonic oxide	7·92	4·97
Carbonic acid	0·30	0·00
Nitrogen	1·00	4·40
Oxygen	0·43	0·30
	103·45	103·00

The substitution of olefiant in place of the volume of condensable gases causes the total volumes to be represented by 103·45 and by 103 instead of 100; but as some, if not all of the actual light-yielding gases must certainly have a higher calorific power than olefiant, we may fairly calculate the heating power of 100 volumes on the basis of the greater number. If any reduction were made, it should be by subtracting in each case the excess volume from the hydrogen, and thus reduce hydrogen to 45·25 and 46·33 respectively, instead of 48·7 and 49·33.

A table (compiled by the late Dr. Letheby, from various trustworthy sources) of the calorific powers of gases and of some other substances, inclusive of that of coal gas itself, as determined by the late Mr. F. J. Evans, is given in the report of the proceedings of this Association for 1866.* The powers for the gases in question are, as given in that table—

	Pounds of Water heated 1° Fahr. Per Cubic Foot.	Per Pound of Substance.
Hydrogen	329	62,030
Marsh gas	996	23,513
Olefiant	1585	21,344
Carbonic oxide	320	4,325
Common coal gas	650	21,060
Cannel coal gas	760	20,140

Multiplying the percentages of the combustible gases in Table II. by the appropriate numbers, as above, we obtain in the result the calorific power due to 100 cubic feet:—

Frankland.	Calculated Power.	Humpidge.	Calculated Power.
H . . 48·70 × 329	= 16,022·3	.. 49·33 × 329	= 16,229·6
CH_4 . . 38·20 × 996	= 38,047·2	.. 37·00 × 996	= 36,852·0
C_2H_4 . 6·90 × 1585	= 10,936·5	.. 7·00 × 1585	= 11,095·0
CO . . 7·92 × 320	= 2,534·4	.. 4·97 × 320	= 1,590·4
	67,540·4		65,767·0

or, in round numbers, 680 and 660 units per cubic foot.

To find the calorific power per pound of coal gas, we must find its specific gravity, and therefore must first find the density of the condensed gases. This can be readily done with tolerable exactness. One cubic foot of olefiant weighs 525·7179—say 526 grs., and by weight contains 24-28ths, or 6-7ths, of carbon. The respective weights of these elements must then be—Carbon, 450·86; hydrogen, 75·14; total, 526·00. 6·9 volumes, as per Table II., must contain—

Carbon	6·9	×	450·86	= 3110·934
Hydrogen	6·9	×	75·14	= 518·446
				3629·380

But the 3·45 cubic feet of $C_n H_m$ in Table I. contained the same weight of carbon, or . . . . . 3110·934
The weight of hydrogen in the olefiant is . . . . . 518·446 grs.
But gives an excess volume of 3·45 cubic feet. One c. ft. of hydrogen weighs 37 grains; hence 3·45 × 37 = 127·650 „

Weight of hydrogen in condensed gas . . . . . 390·796

Weight of 3·45 cubic feet of condensed gases . . 3501·730

This divided by 3·45 and then by 535·9 (weight of a cubic foot of dry air) gives the gravity as 1·894. In the same way the gravity of the condensed gases $C_n H_m$ of Mr. Humpidge's analysis will be found to be 1·665.

We can now compute the weight of 100 cubic feet of the gases by multiplying the weight of each constituent gas by its gravity and by the weight of a cubic foot of air as in Table III., or by the weight of a cubic foot of each gas as in Table IV.

* See JOURNAL, Vol. XV., p. 499.

TABLE III.

	Frankland.				Grains.	lbs.
H	48·70	× 0·0692	× 535·9	=	1,805·98	0·258
CH_4	38·20	× 0·559	× „	=	11,443·61	1·635
$C_n H_m$	3·45	× 1·894	× „	=	3,501·78	0·500
CO	7·92	× 0·973	× „	=	4,129·74	0·590
CO_2	0·30	× 1·524	× „	=	245·00	0·035
N	1·00	× 0·972	× „	=	520·90	0·743
O	0·43	× 1·06	× „	=	244·26	0·035
Weight of 100 cubic feet					21,891·20	3·796
Weight of one cubic foot			218·912			

Weight of one cubic foot of air 535·9 = 408 sp. gr.
32 cubic feet weigh 1 lb.

TABLE IV.

Humpidge.				
H	49·33	× 37·08	(weight cubic feet)	1,829·16
CH_4	37·00	× 299·59	„	11,084·83
$C_n H_m$	4·00	× 898·27	„	3,569·08
CO	4·97	× 521·53	„	2,592·40
CO_2	0·00	× 816·71	„	—
N	4·40	× 521·00	„	2,292·40
O	0·30	× 568·05	„	170·42
Weight 100 cubic feet in grains				21,337·89
Weight of one cubic foot		213·38		
Weight of one cubic foot of air		535·90	= ·398 sp. gr.	
33 cubic feet weigh 1 lb.				

Multiplying 32 by 680, the calorific power of 1 lb. of Dr. Frankland's gas is shown to be 21,760 units; while 33 multiplied by 660 gives 21,780 units for Mr. Humpidge's gas.

According to the data furnished by the careful experiments of many scientists of eminence, such as Andrews, Favre and Silbermann, Regnault, Berthelot, and others, in melting ice and in raising water from about 32° Fahr. to a few degrees above this temperature, by the combustion of the several gases which give heating power to coal gas, the foregoing calculations represent the highest calorific effects which are obtainable with what we recognize as 15 or 16 candle gas. Whether, as before observed, a mixture of heat-yielding gases gives a higher result than that represented by the sum which results from the addition of their respective powers, remains to be proved. I long since suspected such to be the fact, from certain experiences with a mixture of hydrogen and carbonic oxide, while certain engineering friends of mine entertain very strong convictions in favour of this proposition. For the present, however, we can only make our calculations upon the data accepted by the scientific world, and generally believed to be correct.

In the ordinary use of coal gas for heating water, its calorific power is much below that shown by calculation. Very much of the heat passing off to waste with the products of combustion and the nitrogen associated therewith, and more sometimes with the excess of air, which coming into contact with the vessels in which water is being made hot, becomes greatly raised in temperature, and carries away heat.

Let us suppose, first, that water is being kept boiling; secondly, that only the quantity of air needful to burn the gas is supplied, and comes into contact with the vessel containing the water; and, thirdly, that the products pass off at no higher temperature than 212° Fahr. Adding up the respective weights of hydrogen and carbon in the gas, as per Table IV., we find that we have the following results:—

TABLE V.

Hydrogen.		Carbon.
H	0·258	
CH_4 4-16ths of 1·635 . . .	0·409	12-16ths of 1·635 . . . . = 1·226
Condensable gases, as per calculation	0·056	. . . . . 0·444
	0·723	1·670
Oxygen required to combine with H, 728 × 8	5·784	Oxygen required to combine with C, 1·67 × 2·67 . . . 4·459
Water produced	6·507	CO_2 produced . . . . . 6·129
		Add CO . . . . . 0·300
		Plus 4-7ths of 0·3 to form CO_2 . . . 0·176
		Carbonic acid . . . . . = 6·605

Thus the products from 100 cubic feet of such gas is 6·507 lbs. of water as steam, and 6·605 lbs. of carbonic acid. In the formation of steam 967 units of heat are rendered latent or insensible to the thermometer. Multiplying the pounds of steam produced (6·507) by 967, the product is 6392·27. The specific heat of carbonic acid is 0·2164; that is, 1 lb. of water requiring an amount of heat which we call *one* to raise it 1° in temperature, 1 lb. of carbonic acid requires less than one-fourth of such heat to raise it 1°. Multiplying the weight in pounds of CO_2 (6·605) by 212° Fahr., and by 0·2164, the product is 303. The 10·419 lbs. of oxygen burned is, however, associated with 3·35 times its weight of nitrogen, or 34·9 lbs. Multiplying this by 212°, and by the specific heat of nitrogen (0·244), the product

is 1805·3. Adding these three products together, we find that the total is 8500 units. Subtracting this from 68,000 (the unit power, in round numbers, of 100 cubic feet of gas), we have 5950 units per cubic foot of gas, or one cubic foot would give only 595 units of heat instead of 680. Practice, however, teaches us that at least twice the quantity of air needed for combustion is heated up in ordinary operations. This extra quantity would weigh 45·319, and this multiplied by 212° Fahr. and by its specific heat (0·2379) gives 2286. Deducting this from the reduced power, 59,500, the remainder is 57,212, or 572 units per cubic foot.

In ordinary use we fail to realize this amount of heat by fully 200 units. In a long course of carefully conducted experiments, I took a Bunsen burner with four $\frac{3}{8}$-inch tubes as a standard, inasmuch as the results it gave were higher than that realized with any other. No doubt, because the heat was delivered exactly about the centre of the vessel, and before escaping traversed the bottom more completely than the heat from broader burners. The indicated calorific powers, after correction for barometric pressure and for the temperature—which correction it is quite as necessary to make in respect to gas used experimentally for heating as it is for gas when tested photometrically—ranged from 365 to 392; the water being raised from various temperatures between 40° and 60° up to 210° or 211°, and the average result being 382 units per cubic foot. Under similar conditions, and using each burner in such manner, and with such rate of consumption as was found to give the highest effect, a cluster of small fishtail burners gave results equal to 98 per cent. of the standard; an 8-tube Bunsen, 92 per cent.; Wallace's solid flame, 97 per cent.; a common 1s. article, which I think is called the "Egyptian," 91 per cent.; another known as the "Déposé," 83 per cent. One, which is much vaunted as excelling all others by its very modest constructer, gave 93 per cent.; and a larger one of the same kind 87 per cent., with the accompaniment of a detestable smell if the rate of consumption were increased unduly to a very trifling extent. Taking the average of the results realized with the best and with all the many other gas-stove boilers tested, we have 360 units indicated as the power of the gas per cubic foot in raising water to 210° or 211° Fahr. If, as I believe, the real power of the gas employed was, on the average, 680 units, 320 units, or 47 per cent. of its heat, were lost. The experiments made by myself during the past two years only confirm others which I have made at intervals during a number of years, and agree perfectly well with those made by Mr. Lewis Thompson with the gases of several companies in the years 1852–3; the average result of his experiments being 374 units per cubic foot.

It may be stated as a broad general fact, that the higher the temperature to which water is raised in an open vessel, by the aid of gas or other fuel, the smaller will be the amount of heat utilized. Indeed, this fact holds good with the things called water-heaters, which can scarcely be regarded as open vessels. With a water-heater and water raised only a few degrees between 40° and 60°, I realized nearly 600 units in the water, but when the water was raised much higher the realized units sank to below 400. Another heater at its best gave only 390 units, while with a large cylindrical pot, charged with 10 gallons of water, 370 units were secured on the same occasion. I have tried vessels with jackets of non-conducting material, but the difference produced was so insignificant as to render it unadvisable to complicate burners for the use of the public by such additions.

When, some months since, I intimated to the Secretary that I was willing to provide a paper on this subject, I entertained the hope and expectation that I should be able to present at this meeting a simple calorimeter by which the heat-power of combustible gas might be readily and easily ascertained; but, although I have not spared effort, I have not yet been successful. I hope, however, presently to accomplish the task, which to me is a most interesting one. I cannot but regret my inability on this occasion to place before you statements of the actual heat-power of the same gas, as deduced from experiment, and from analysis and calculation.

What results ordinary London gas should produce in heating water, have been shown, as far as calculation goes. We have now to consider what weight and volume of air would be raised 1° Fahr. by a cubic foot of such gas.

Atmospheric air weighs, when perfectly dry, 535·9 grains per cubic foot; but under natural conditions, and at normal pressure and temperature (30 in. bar., 60° Fahr.), a cubic foot contains 5·8 grains of water vapour, which is lighter than air, so that a cubic foot of such moist air weighs only 532·4 grains. As 7000 grains are equal to 1 lb. in weight, it follows that the volume of 1 lb. of moist air is 13·148—say 13·15 cubic feet. Dividing this number by the specific heat of air, 0·2379—say 0·238—the quotient is 55·25, which multiplied by 680, the calculated number of water units per cubic foot of gas, gives 37,570 cubic feet of air as the volume which would be raised 1° Fahr. This is on the supposition that the products of combustion mingle with, and form part of the volume of air heated, and without regard to the little differences in the specific heat of CO_2 and of nitrogen as compared with air. It is based also upon the assumption that the whole of the heat absorbed and rendered sensible in the water of combustion is given up as sensible heat, which might be the case if air were raised 1° from about 32°; but as it generally happens that the air is required to be raised a considerable number of degrees above that of the external atmosphere, the water vapour produced is insufficient to saturate the heated air. Such being the case, we lose the latent heat—at least, so it appears to me. Besides which the water vapour must be raised to the same temperature as the air, and *its* specific heat is 0·475; so that it requires just twice the heat which air does to raise a given weight through an equal number of degrees. The loss in water units for heat rendered latent in the water vapour was found to be 6392·27 per 100 feet of gas—say, 64 units per foot—which, multiplied by 55·25, gives the cubic feet of air to be deducted from 37,570, and leaves 34,034 cubic feet of air as the maximum volume which could, by any possibility, and according to the accepted data, be raised 1° Fahr. by the combustion of one cubic foot of London gas. With cannel gases, the proportion of hydrogen to the hydrocarbon gases is much less than in common coal gas. Hence less loss ensues in respect to heat rendered latent.

In conclusion, I may say that I have reasoned on lines which I think are correct, but which may be open to challenge at some points, and I cannot but again express my regret that I have been obliged to limit myself mainly to mere calculations, based upon analyses of coal gas. On some other occasion I hope to lay before you the results arrived at by precise experiments. What I have said, however, is sufficient to show that in ordinary use we lose a tremendous amount of heat, which loss we may hope will be reduced by improvements in boilers and boiling appliances, even as the loss has been very greatly reduced in gas-cooking ovens. In the meantime, do not let us be too severe on gas-stove makers, whose instruments (some very cheap), for the most part, do as well, or nearly so, as burners of the very best construction, when used with great discretion and care.

(V.)

ON THE HEATING POWER OF COAL GAS.*

By Dr. James Adams, of Glasgow.

The heating power of coal gas is, and must always remain an unsettled quantity; for coal gas is not a pure elementary substance of homogeneous composition and of fixed properties, but, on the contrary, is a very variable mechanical mixture of numerous gases and vapours, the proportions and number of which differ according to the nature of the coal and of the special manufacturing processes employed. These conditions are tacitly assumed with reference to the "candle power," as it is technically called. Therefore no chemist or gas engineer speaks of "*the* candle power" of coal gas as if this was a fixed quantity; he knows that the candle power varies with every sample of gas, and may range from 10 to 50 candles or more.

In treating of the thermal effects of gas combustion, the term "units of heat" is employed in contra-distinction to "candle power." The quantity of heat that is capable of raising 1 lb. of water through 1° Fahr. is called the British unit of heat. The unit may, however, be that of one grain or of one ton of water, but unless so qualified the expression "unit of heat" signifies a pound unit.

Light and heat being identical forces, it might *à priori* be assumed that a range in heating force may correspond to a range in candle power, but I am not aware that such an analogy has been suggested. The disposition hitherto seems to have been all the other way, and there are parties who speak of *the* unit contained in *the* cubic foot of gas, as they

* We have been asked by the author to publish the following statement:—"This communication, as made public at the meeting of the British Association of Gas Managers, on June 15, was read from an *unrevised proof*, the corrections upon which arrived too late for the hour of meeting. Press errors and errors in figures, &c., have been thoroughly revised and corrected in the present reprint. For instance, in the paper read at the meeting the weight of one cubic foot of oxygen was set down in Table IV. at 312·384 grains, instead of 624·768 grains; and, through this error, a number of little errors affecting absolute accuracy, but not interfering with substantial conclusions, had crept into several of the calculations, from whence they have now been eliminated."—Ed. J. G. L.

would speak of *the* pennies contained in half-a-crown, or of the number of grains contained in 1 lb. avoirdupois; and among the better informed, although still not sufficiently informed, there is no common agreement. In a few instances only has there been even an attempt to bring the heating value of coal gas within limits. In the first, as in the late edition of that standard work of reference, "Box on Heat,"* the author refers to experiments of General Morin on the temperature and volume of air currents in a chimney heated by gas, and to observations made by Pêclet on the flame of an oil lamp, and comes to the conclusion that "the total heat" of coal gas is 696 units per cubic foot. The late Dr. Letheby states† that the heat of "common coal gas" is 650 units, and that of "cannel coal gas" 760 units per cubic foot; and beyond this distinction makes no other qualification. Mr. Kinnear Clark‡ lays down explicit rules from which to estimate the heat of coal gas, and from these he calculates that a gas analyzed by Mr. Owen Ross§ showed 45,900 units per pound weight, or 1466 units per cubic foot; but being doubtful that this estimate was in excess of ordinary coal gas, he, in a general reference table, gives as "the mean of Ross and Harcourt" that the heating power of 1 lb. of coal gas is 34,292 units. Mr. Harcourt's estimate of a gas analyzed by him‖ is 22,684 units per pound, or 756 units per cubic foot. But Mr. Ross's table and Mr. Clark's conclusions are seriously affected by certain errors which I will correct at a more advanced stage of my argument. With reference to Mr. Harcourt's table of analysis—the best and most usefully constructed I have seen—there is between us an important difference in the *principle* on which he has based his estimate of heating power, and on which I base mine. When I come to deal with this principle, I have no doubt Mr. Harcourt will be first to admit that I have pointed out a serious fallacy. These are the only examples, so far as I have ascertained, wherein a precise determination of the heating power of coal gas has been made on the basis of scientific estimate.

To Dr. W. Wallace, of Glasgow, is due the merit of opening up the question from a standpoint that gives really tangible results. In a very brief but valuably suggestive paper,¶ Dr. Wallace, after premising that, "as regards the heating power of coal gas we have no definite information," gives the results of some experiments on three qualities of coal gas, in which he estimates that he "realized about 55 per cent. of the theoretical heating power." From his data I calculate that his three samples contained theoretically 631, 827, and 949 units per cubic foot. Dr. Wallace further calculates the value in heating force of two gases analyzed by Dr. Letheby, and estimates that the first was of ·387 specific gravity, and of 21,222 units per pound of gas, or 621 units per cubic foot; and of the second the specific gravity was ·506, the heat units per pound 21,157, and 819 per cubic foot. To the extent to which they are carried, Dr. Wallace's observations are fairly reliable, and I can find no others that are equally valuable. They are what he terms "simple but instructive experiments," making no pretensions to the character of absolute determination. But although no elaborate investigation has been made of the heating power of coal gas in its entirety, such observations have been made on the elementary constituents, particularly on hydrogen and carbon, which in their various combinations essentially compose coal gas, and also upon the compounds in which these elements are united.

But there is no standard of heating force, no absolute measure of heat, and the calorific power of a fuel can only be estimated relatively, by comparing the effects produced by equal weights of different kinds of fuel. And notwithstanding the highest chemical skill engaged in investigating the heating values of the combustible elements of fuel, it cannot be said that more than rough approximations have yet been reached. On this point there exists much mistaken belief, and there is too great a tendency to assume that the landmarks, as they may be termed, which are being affixed from time to time by chemists in their explorations of this wide domain of science, represent an absolute survey. This is far from true. An absolutely accurate determination of the heating power of any of the components of coal gas—say hydrogen—can only be made through the use of certain instruments of precision, *inter alia*, a calorimeter not liable to fallacy. But different observers have modified the construction of the calorimeter they employed, on the express ground that they are thereby avoiding errors inherent in the instruments used by their fellow-investigators. Consequently the heating power of hydrogen has been appraised at values that are widely apart. Of these it will be instructive to cite a few examples. According to Dulong, 1 lb. of hydrogen is capable of producing heat that will raise the temperature of 62,535 lbs. of water through 1° Fahr. Very recently one of my friends, a professional chemist of the foremost rank, made, at my request, a calculation of the heating power of a certain coal gas, and he employed Dulong's estimate. Another professional friend, of eminent ability, likewise made an estimate of the same gas, using for his basis the more widely accepted figures of Messrs. Favre and Silbermann, who gave the value at 62,032 units per pound. The first estimate given to me is 21,511 units per pound of the coal gas, or 794 units per cubic foot; the second is 20,967 units per pound, or 774 units per cubic foot. My own estimate for the same gas is 20,736 units per pound, or 765 units per cubic foot. Who shall determine the accuracy of these three estimates? or is any one of them reliable? Messrs. Favre and Silbermann's estimates have, for many years back, held the highest place in the confidence of their chemist *confrères;* but the motto of the modern chemist seems to be "Excelsior," and in Professor Andrews we have a high authority, and also an original and still more recent investigator, and his estimate for hydrogen is 60,986 units. Older authorities than any of those quoted—viz., Despretz, Laplace, and Clement—have respectively appraised hydrogen at 42,552, 42,120, and 39,807, and with many these are still names to conjure with.

Thus we see that, according to the accidental preference for an authority, or it may be, at times, from non-acquaintance with other authorities, there are multipliers being used of the extreme values I have specified. Meanwhile the estimates of Messrs. Favre and Silbermann and of Andrews are in some respects getting out of date, or it may be are getting modified to a point nearly approaching accuracy, as is shown in Gmelin's "Handbook of Chemistry," a new edition of which is now publishing in Germany. In that great work of reference, all the more important combustibles are discussed in the light of the most recent investigations, and very material corrections upon some hitherto accepted valuations have been made. With respect to hydrogen, the latest, and I am assured the most reliable estimate, that of Thomsen, of Copenhagen, must now be taken at 61,524 units. Carbon, by almost unanimous agreement, is taken at 14,544 units, and these are the numbers I have adopted in the calculations made by myself in this communication. The figures for compounds of carbon and hydrogen found in coal gas will appear farther on, and they also are the values accepted as most reliable in Gmelin's "Handbook." And in this connection I remark that it is too much taken for granted that the formulæ used in chemical calculations are so familiarly known as to require no explanation, and that there is but one way of calculating the specific gravity of a gas, or determining its volume, &c. The fact is so much the opposite, that I have frequently heard half-a-dozen methods proposed, and seen them worked out, to determine a point of seeming simplicity; and I have frequently found, in testing one method against another, that an unsuspected fallacy has become apparent in a method that at first sight seemed open to no challenge. I will therefore make plain, in an appendix note, any points that are not self-evident in the tables of calculations that will follow in due place.

Another fallacy and serious cause of discrepancy arises when it is assumed that the heat of combustion of a compound is the same as that of its elementary constituents. This view calls for protest and for emphatic comment. In general it is not only erroneous, but the fact is usually the reverse. Thus marsh gas, which forms more than one-third of the *bulk* of coal gas, is composed of three parts by *weight* of carbon and one part by weight of hydrogen. In 1 lb. of marsh gas, the heat of combustion of its elements, *when they are burned separately*, is for carbon 10,914 units, and for hydrogen 15,381 units, making a total of 26,295 units as the combined heats which 1 lb. of marsh gas ought to yield. But by actual experiment the heat evolved is only 23,616 units; hence marsh gas, in burning, evolves 2672 units per pound less than its elements—less than its potential heat, as shown by calculations. In explanation of these phenomena it is supposed that the combination of carbon and hydrogen to form marsh gas is accompanied by evolution of heat, and that their separation from the state of combination in the act of combustion is also attended by the disappearance of an equal quantity of heat. These suppositions have received direct experimental confirmation, for if one volume of marsh gas is passed through a white-hot tube, it is resolved again into hydrogen and carbon,

* 2nd ed., 1876, p. 27.
† *Chemical News*, July, 1866.
‡ "Manual of Tables and Data," 1877, pp. 445, 769.
§ "Air as Fuel."
‖ Proceedings of the Institution of Civil Engineers, vol. xl., p. 150.
¶ Proceedings of the Philosophical Society of Glasgow, 1879.

and if these elements, after being thus dissociated, are burned separately, they give out the full number of 26,295 units due to the individual elementary substances. In their dissociated state the elements of marsh gas occupy more than double the space they do when combined, and in condensing into half the volume which hydrogen occupies in the free state there is supposed to be sustained a loss of molecular movement. When, therefore, they are burned after separation, they again give out the 2672 units that had disappeared—a proof that they have again regained their due amount of molecular movement.

These phenomena are observed in varying degrees in the combustion of all the compounds of carbon and hydrogen, and these degrees are not the result of any law yet discovered. Some of these compounds evolve practically in their combustion nearly as much heat as is shown to be possessed in their elements; *in certain instances even more*, as in olefiant, ethylene, and benzole. To increase the difficulty of this problem, it has been found that certain isomeric substances—that is, substances identical in composition—by no means give out equal heat when burned. Thus oil of lemons, oil of turpentine, and terebene have the same formula of composition—viz., C_{10} H_{16}—and the same molecular weight—viz., 136; but on combustion they give out different quantities of heat—viz., 19,100, 19,500, and 19,700 units respectively for a given quantity. In Watts's "Dictionary of Chemistry," the best digest of modern chemical science in this country, among other commentaries on this unsolved problem, it is laid down, with reference to the number of heat units estimated for particular substances, that "many of these numbers must be regarded as approximations, and sometimes as not very close approximations to the truth. The chief causes of uncertainty with regard to them, besides the difficulties inherent in the experimental determinations themselves, are the different calorimetric properties of the substances examined—differences, that is, in regard to specific and latent heats, and in some instances their admitted doubtful purity. Hence it is impossible to trace any exact correspondence between the composition of the bodies experimented upon and the amount of heat which they evolve upon combustion."

After these preliminary and very necessary considerations, I shall be better followed in my illustrations of estimates of the heating power of coal gas, beginning with my promised commentary on the valuations of Mr. Ross, Mr. Clark, and Mr. Harcourt.

According to Mr. Ross, the gas already referred to was supplied by the Chartered Gas Company, London, was of specific gravity ·420, and was composed as shown in

TABLE I.

	Carbon.	Hydrogen.	Total.
Illuminating hydrocarbons, or olefiant gas (bicarburetted hydrogen, C_2H_4)	3·096	0·434	3·530
Marsh gas (carburetted hydrogen, CH_4)	26·445	8·815	35·260
Carbonic oxide	3·840	5·110	8·950
Hydrogen	—	51·800	51·800
Nitrogen	—	—	0·380
Oxygen	—	—	0·080
	33·381	66·159	100·000

Of this table Mr. Clark states: "The total heating power of 1 lb., or 31·3 cubic feet, at 62° Fahr., of this gas, is by rule 4, p. 406, 'Manual of Tables,' &c., *op. cit.*, 45,900 units; . . . of one cubic foot, the total heating power is 1466 units of heat. . . . It is doubtful whether the power of average coal gases is so great as is here stated."

The first point calling for comment is the improper manner in which the table is framed. Mr. Ross has set down carbonic oxide as composed of carbon and hydrogen, although carbonic oxide contains no hydrogen, but is composed exclusively of carbon and oxygen; and he thus gives a total for hydrogen of 66·159, instead of 61·049. The figures 5·110 should therefore be removed from the hydrogen column and carried to the general total column on the line with oxygen. This, no doubt, is a clerical error, but it misleads a person of imperfect information, or individuals of the incautious class, who so readily take printed figures for indisputable facts, and who may possess only the capacity of making an A B C arithmetical calculation. The next point involves Mr. Clark, who has erroneously assumed that Mr. Ross's table represents *weights*. But the table represents *volumes*, and Mr. Clark has calculated for weight, with the result of more than doubling the proper number of heat-units. If the composition had been given by weight, the figures for the four constituents enumerated would have been H, 24·8; C, 59·2; O and N, 16. My first glance at the hydrogen column startled me, and led me to unravel what was so obviously a great error. The units of heat for this gas, which Mr. Clark places at 45,900 per pound, or 1466 per cubic foot, are, when properly computed, 22,126 units per pound, or 637 units per cubic foot. The volume of the gas, which is placed at 31·3 cubic feet per pound at 62° Fahr., should be 34·8 cubic feet per pound, and the specific gravity, which is given at ·420, should be ·356. The detailed calculations through which these corrections are made will be found in an appendix note. I have dwelt thus long on this unlucky table because it is prominently quoted, and more than once referred to, as a typical illustration, not only of the heating power of coal gas, but also of the proper mode of computing the heat, in an important, and in many other respects valuable book of reference. Mr. Clark is a master of figures, is moreover the able editor of that excellent work "On Fuel: Its Combustion and Economy," and he unquestionably possesses all the necessary fulness of information; so that I have no doubt his having slipped into a wrong groove in dealing with this table has been accidental—a false step at starting.

Mr. Harcourt's table of his analysis of a coal gas, together with its accompanying estimate, is here reproduced, and it is a good illustration of one of the serious fallacies to which I have directed attention:—

TABLE II.

	Carbon. lbs.	Hydrogen. lbs.	Oxygen. lbs.	Total. lbs.
Olefiant gas	10·5	1·7	—	12·2
Marsh gas	39·7	13·2	—	52·9
Carbonic oxide	5·9	—	7·9	13·8
Carbonic dioxide (carbonic acid)	1·9	—	5·0	6·9
Hydrogen	—	8·1	—	8·1
Nitrogen	—	—	—	5·8
Oxygen	—	—	—	0·3
	58·0	23·0	12·9	100·0

Of this gas it is stated that the analysis shows the composition of 100 lbs., or "about 3000 cubic feet," and that 1 lb. had a volume of 30 cubic feet at 62° Fahr. The heating power is alleged to be "*about* 22,684 units, and of one cubic foot 756 units." Owing to the vagueness of the expression "about," which is applied both to the volume and to the units, I have re-computed this estimate, first according to weight as it is given, and again by converting the weight into volume. I bring out the number of cubic feet at 3104 for the 100 lbs. instead of 3000, and 31 cubic feet per pound, instead of 30. In computing the heating value, instead of 22,684 units per pound, or 756 units per cubic foot, I bring out the value at 20,702 units per pound, or 666 units per cubic foot. So far as the gross number of units are concerned, the great discrepancy between our estimates does not, in my belief, arise from arithmetical error on Mr. Harcourt's part, but from the principle on which his calculation is based. He has calculated the heats of combustion as they would be evolved by the elementary constituents if burned separately, and this method of estimating I have already shown to be fallacious. He has, moreover, reckoned the carbon entering into the composition of carbonic acid, while carbon so combined contributes no heat whatever. The carbon in carbonic oxide is also reckoned at its full calorific value, although when burned as carbonic oxide there is evolved little more than two-thirds of the heat due by carbon when uncombined.

The foregoing commentaries, which are of general application, will, I hope, aid a right appreciation of Table III. It embraces the analyses as published of twelve coal gases, and in one instance a mean of six analyses is comprised in a single estimate. The series is fairly typical, and, being computed on a uniform method and on a uniform principle in relation to the heating values of the constituents, it is as nearly accurate for purposes of comparison as the present state of information admits. The conclusions are stated in a form [see Table III., next page] that I trust will prove practically useful for reference.

The first point that deserves special notice in this table is the fact that of the numerous gases, vapours, diluents, and impurities—about twenty in number—that, in varying proportions, are found in coal gas, only ten find a place in these analyses, and they appear to be admitted or excluded capriciously; for some components, such as watery vapour, or sulphuretted hydrogen, which are rarely absent in gas, are noticed in only three analyses. The highest number of ingredients is shown in Bunsen's analysis of Manchester gas, and that is the only analysis in which a place is given to a heavy hydrocarbon other than olefiant. In six examples seven constituents are named, in two instances six ingredients, in one analysis five ingredients, and in two cases four ingredients only are named. From this it is evident that analysts are not at all agreed, either upon the number or upon the importance of the individual constituents that ought to be in-

TABLE III.

Constituents of Coal Gas.	1 Manchester Gas. Bunsen.	2 London Gas. Letheby.	3 London Gas. Letheby.	4 London Gas. Harcourt.	5 London Gas (average). Imperial Co.	6 London Gas (average). Great Central Co.	7 London Gas (average). Chartered Co.	8 London Gas (av. of Six Analyses) Humpidge.	9 London Gas. Frankland.	10 London Gas. Roscoe.	11 House of Parliament. Humpidge.	12 London Gas (Western Co.). Frankland.
	Vols.	Vols.	Vols.	Vols.	Vols.	Vols.	Vols.	Vols.	Vols.	Vols.	Vols.	Vols.
Hydrogen	45·58	46·0	27·7	46·77	41·15	51·24	51·80	47·83	50·28	47·60	41·72	25·82
Marsh gas	34·90	39·5	50·0	38·18	40·66	35·28	35·26	36·94	36·95	41·53	41·88	51·20
Olefiant, or "equivalents of olefiant"	4·08	3·8	13·0	5·03	3·67	3·56	3·53	7·02	6·34	6·97	19·66	22·98
Quartene	2·38	—	—	—	—	—	—	—	—	—	—	—
Carbonic oxide	6·64	7·5	6·8	5·69	8·02	7·40	8·95	5·27	4·37	7·82	4·98	7·85
Sulphuretted hydrogen	0·29	—	—	—	—	—	—	—	—	—	—	—
Carbonic acid	3·67	0·6	0·1	1·81	0·29	0·28	—	—	—	—	—	0·13
Nitrogen	2·46	0·5	0·4	2·39	5·01	1·80	0·38	5·29	—	—	2·71	1·51
Oxygen	—	—	—	0·10	1·20	0·44	0·08	0·56	—	—	—	0·43
Aqueous vapour	—	2·0	2·0	—	—	—	—	—	—	—	—	—
Heating power from combustion of constituents in state of combination—												
Heat units . . . . . per lb.	18,860	21,290	21,181	20,702	18,858	21,542	22,126	20,644	23,679	22,739	21,987	20,778
Do. . . . . per cub. ft.	696	663	863	666	658	632	637	690	655	747	992	1,041
Heating power from combustion of elementary constituents separately burned—												
Heat units . . . . . per lb.	20,736	22,777	22,848	22,586	20,763	23,365	24,112	22,415	26,492	24,693	24,237	22,238
Do. . . . . per cub. ft.	765	709	931	727	729	686	693	748	732	811	1,019	1,114
Candle power	21	12	20	—	16	12	12	16	12	13	20	34
Specific gravity	·457	·387	·506	·399	·432	·363	·356	·411	·342	·406	·526	·620
Cubic feet per pound	27·09	32·10	24·53	31·06	28·64	34·06	34·79	29 95	36·15	30·44	23·59	19·96
Grains weight per cubic foot	258·345	218·043	285·314	225·373	244·366	205·474	201·175	233·674	193·607	229·152	296·631	350·619
Heat units less per pound in combination than is evolved by elements separately burned	1876	1487	1667	1884	1905	1823	1986	1771	2813	1954	2250	1460

cluded in the inventory. This is a state of things that opposes an effectual barrier to definite conclusions. One important fact is, however, made broadly apparent—viz., that the heating power of coal gas theoretically estimated is not a *fixed quantity*, neither is it measurable by the *cubic foot*. The table does not embrace an extreme range, and yet it shows that from 632 to 1041 units may be contained in a cubic foot of gas, or from 18,858 to 23,679 units in 1 lb. of gas—a variation and a range so great as not to admit of a safe average. It will be afterwards suggested, on probable grounds, that with a more comprehensive qualitative analysis a higher estimate might be formed. The last line in the table deserves special notice, for it demonstrates that an average exceeding 8 per cent. of heat units becomes absorbed or latent in the elementary constituents when they are in a state of combination. In other words, there is from 8 to 9 per cent. less of heat units evolved by the combustion of coal gas in its entirety than is given out by its elementary constituents when separately burned. *The heating power is seen to increase with the specific gravity;* but the numbers in this table are not sufficient to permit of more than the statement of this general conclusion. As a rule, the candle power is appraised on a very vague foundation, sometimes from the ratio of heavy hydrocarbons, and sometimes on the simple fact that one gas is what is termed a cannel gas and another a common coal gas. But it may be safely taken that the heavier the gas the greater is the heating power, bulk for bulk. In so saying, it is assumed that the gas is commercially pure—*i.e.*, containing little or none of that heavy component, carbonic acid, which does not contribute to, but detracts from the heating as well as the lighting value, and also that there is no considerable excess of carbonic oxide, which has little heating force in comparison with the other carbon compounds. Excluding these components—viz., carbonic acid and carbonic oxide —the weight of gas is an important factor, for it indicates the presence of carbon; and the greater the amount of carbon, unless in the objectionable forms just referred to, the greater the heating power. Very much, therefore, depends upon the form in which this element is present. For carbon and hydrogen are capable of uniting in proportions of the extremest variety, and with each variation the bulk may remain little altered, so that the same quantity by weight of these substances may be so combined as to occupy in one sample a volume contracted to 20 cubic feet for 1 lb. of weight, and in another a volume expanded to 36 cubic feet for 1 lb. of weight. In the first case it is obvious that the heating power will be more effective because the material of combustion is more concentrated. Referring to Table III., gas No. 12, this gas contains 24,632 grains of carbon and 6801 grains of hydrogen, or a total substance of 31,433 grains in 100 cubic feet. But gas No. 6 contains only 11,715 grains of carbon and 5034 grains of hydrogen, or a total substance of 16,749 grains in 100 cubic feet. From these facts it is evident that no expression as a measure of value can be more misleading than that of "the heat of a cubic foot of gas," unless associated with the number of cubic feet that are contained in 1 lb. weight of the gas referred to.

The heat-evolving constituents of gas fuel, as indeed of all fuels, consist, with insignificant exceptions, of hydrogen and carbon, the former possessing the highest amount of heating power in proportion to weight, but very much the lowest in proportion to bulk; and I have just shown that it is mainly through the amount of condensation which these elements undergo in their combinations that the heating value of a cubic foot of one coal gas so far exceeds another. The same holds good with respect to the illuminating properties. For many years the highest place has been accorded to heavy carburetted hydrogen, familiarly known as olefiant gas. It was for long considered the true illuminating principle of coal gas, until it was pointed out, chiefly by Dr. Frankland, that there were heavy and also condensable hydrocarbons other than olefiant to which illuminating properties should be likewise attributed in large measure. These he termed "the equivalents of olefiant," and there has grown up the practice of lumping together, without discrimination, all the heavy hydrocarbons that are found in coal gas, and calling them "heavy hydrocarbons, the equivalents of olefiant." But it is by no means certain that the thermal values of these heavy hydrocarbons are equivalent to that of olefiant. It has indeed now come to be taught that the true illuminating principle of coal gas should properly be attributed to benzene or benzole vapour, as it is indifferently termed, and it has been shown—quite in accordance with the analogy I have suggested—that, besides its high illuminating property, benzene has a calorific force far exceeding olefiant. Benzene, although known to be present in coal gas, has hitherto been so little regarded that I am not aware of any analysis, with one exception, where its volume in proportion to other constituents of coal gas has been determined. This exceptional analysis was made by Berthelot,* who has shown that the proportion of olefiant in some gases of good luminous quality is exceedingly small—in that of Paris only 1-30,000th part of a percentage —while benzene was present in the proportion of 3 to 3½ volumes in 100. Professor Dittmar has made very valuable experimental observations in this connection. He has shown that a mixture of hydrogen and olefiant, in so large a proportion as equal parts by volume, burns with an almost non-luminous flame; while hydrogen, containing so little as only 3 volumes of benzene in 100—as near as may be the proportion found by Berthelot in Paris gas—burns with a very bright flame. Frankland and Thorpe have followed up these researches, and have more recently determined the illuminating power of benzene in combination with hydrogen, with carbonic oxide, and with marsh gas (to the exclusion of olefiant), in various proportions, and found that they gave

* *Comptes Rendus*, lxxxiii.-iv., 1877.

the light of from 70 to 94 candles, thus confirming the observations of Berthelot and Dittmar. The natural deductions from these investigations are that the illuminating power of coal gas is due mainly to the presence of benzene, and that the intensity of a flame is not owing to the numerical relation of the carbon to the hydrogen, as was formerly assumed by Frankland, but to *the condensation of their elements in the unit or molecule of fuel.* "It is highly probable," says the author of the article on "Gas," in the Encyclopædia Britannica, 1879, "that the illuminating value of coal gas depends much more on the presence of benzole vapour than on the proportion of the heavy gaseous hydrocarbons, and the estimation of benzole in the gas is a point which has hitherto been comparatively neglected."

The bearing of this special reference to one of the heavy hydrocarbons, hitherto confounded with others of less illuminating or heating value, will be better appreciated after a careful consideration of the next table, in which I have calculated the weight in grains of one cubic foot of the chief constituents of coal gas, and have shown, in parallel columns, their heating power. From the weight so calculated, and with the aid of the other portions of the table, the heat which any coal gas is capable of producing during perfect combustion may be ascertained. It will be found very useful, I believe, as well for general reference as for facilitating calculations connected with the question I am discussing. The fourth column contains the most recent and best approved estimates of heat units contained in the constituents of coal gas fuel, and they are the multipliers I have employed in my estimates. This table powerfully strengthens my argument, that the heating power of coal gas cannot be more than very roughly calculated, either from the gross amount of carbon or of hydrogen separately estimated, or from an estimate based on, and restricted to those few compounds that hitherto have been assumed to represent the total thermal potentialities of coal gas.

TABLE IV.

Names and Synonyms of Constituents of Coal Gas.	Chemical Symbol.	Atomic Weight.	Weight of One Cubic Foot in Grains at 32° Fahr.	Pounds of Water raised through 1° Fahr. by 1 lb. of Gas.	The Weight in Grains of One Cubic Foot of Gas raises, through 1° Fahr., the following quantities of			
					Pounds of Water at 32° Fahr.	Pounds of Air.	Cubic Feet of Air at 32° Fahr.	Cubic Feet of Air at 62° Fahr.
Hydrogen	H	1	39·048	61,524	343	1,442	17,862	16,948
Light carburetted hydrogen—marsh gas—methane	CH_4	16	312·384	23,616	1054	4,428	54,850	58,185
Acetylene—ethine	C_2H_2	26	507·624	21,500	1559	6,551	81,140	86,079
Heavy carburetted hydrogen—olefiant—ethylene	C_2H_4	28	546·672	21,523	1681	7,062	87,491	92,800
Butylene—quartene	C_4H_8	56	1093·344	21,255*	3320	13,949	172,786	183,289
Benzene—benzole vapour	C_6H_6	78	1522·872	21,500*	4677	19,621	243,026	258,239
Sulphuretted hydrogen—hydrogen sulphide	H_2S	34	663·816	7,143	667	2,846	35,250	37,398
Carbonic oxide—carbon monoxide	CO	28	546·672	4,295	355	1,409	17,452	18,518
Carbonic acid—carbon dioxide	CO_2	44	859·056	—	—	—	—	—
Oxygen	O	16	624·768	—	—	—	—	—
Nitrogen	N	14	546·672	—	—	—	—	—
Aqueous vapour	H_2O	18	351·432	—	—	—	—	—
English coal gas	—	—	233·333	22,000*	733	3,084	38,197	40,523
Scotch coal gas	—	—	318·181	22,000*	999	4,202	52,045	55,214

* These figures are only approximately correct.

The enormous differences in the actual and relative heating values of the various combinations of carbon and of hydrogen that form coal gas, are sufficiently illustrated in this table, and it shows convincingly the necessity of estimating the weight of gas in proportion to bulk, instead of the more frequent practice of estimating bulk only. It is seen that the bulk of a cubic foot of hydrogen weighs less than 40 grains, while the same bulk of the gaseous vapour of benzene weighs nearly forty times as much. Moreover, the cubic foot of benzene contains, in a condensed state, 3 cubic feet of hydrogen, and, in addition, a quantity of carbon possessing nearly treble the calorific power of the hydrogen with which it is combined; in short, the same bulk of benzene contains nearly twelve times the heating power of the same bulk of hydrogen. It is therefore very evident that a great difference, as shown by arithmetic, may arise from one hydrocarbon being left out of account and another substituted, an example of which may be given in illustration. Let it be assumed that a coal gas is, from its presumed composition, estimated to possess a heating power of 70,000 units per 100 cubic feet, or 700 units per cubic foot. If 3½ cubic feet are abstracted, and replaced by an equal bulk of benzole vapour, what is the effect of the change? For 2450 units removed in the 3½ cubic feet of gas, there are substituted 16,369 units in the 3½ cubic feet of benzene; 100 cubic feet of the gas thus altered in composition, but unchanged in volume, will now possess 83,869 units of heat, instead of 70,000 units, and each cubic foot will have a heating power of 838 units, instead of 700 units. In the light of recent investigations this hypothetical estimate cannot be regarded as fanciful, and if Berthelot's conclusions regarding Paris gas are extended to coal gases generally, as I think is very probable, it will come to be shown that our present estimates of their heating power, in addition to the liabilities to error already shown, are fallacious to this extent, that one very important factor has been altogether omitted from previous calculations. A true approximation, by calculation, can therefore only be made on the basis of a comprehensive analysis that fairly distinguishes qualitatively and quantitatively the various hydrocarbons.

Meanwhile it is open to infer from some well-marked characteristics what the heating power of a coal gas is likely to be. The number of analyses in Table III. is not sufficient to furnish a good average of coal gases. There is not, I regret to make the acknowledgment, a single analysis of any of our Scotch gases, and it is impossible to frame an average estimate of the thermal value of coal gas that can apply to England, Scotland, and Ireland, from the basis of a few analyses made almost exclusively upon London gas—a quality of gas that rarely exceeds ·500 specific gravity, or 21-candle power. It is my hope that when Scottish chemists are roused to remove what is at present an opprobrium, their investigations will show the quantities of the heavy hydrocarbons in which Scotch cannel coals are admittedly very rich, and also show the possibility—or rather the great probability—that in the presence of benzole vapour, or other hydrocarbons not hitherto accounted for, there may be credit taken in our calculations for a much higher thermal power than has been suspected. But, *quantum valeat*, the average heating power of the carbon and hydrogen in London gas, when the elementary constituents are separately estimated, is shown to be 23,105 units per pound of gas, or 21,199 units if the heats of the elements in their state of combination, as represented, are computed. The difference may be taken at from 8 to 9 per cent. less units for the combination heats. But I have shown that these combinations are represented under names that are only conventionally used, and that for some there should be substituted others of unquestionably higher thermal power than those we are at present forced to accept, through absence of correct information. Meanwhile we can recognize that the combustible elements exist in a proportion that admits of the heating power being increased beyond present estimates; and, on the whole, I think I am justified in setting down 22,000 heat units per pound of gas as an average estimate that is neither lowered nor unduly exaggerated, and it is at least a safe one for the purpose of the present inquiry.

Having reached this stage, I shall now endeavour to establish a practical connection between the candle power, the specific gravity, and the heating power. Fortunately, the determinations of candle power, and also of specific gravity of coal gas are sufficiently numerous to give good averages. From the tables of S. Hughes, Evans, Fyfe, Hislop and others, I have collected about 100 examples in which the specific gravity has been determined in its relation to the candle power; and I have tabulated statistics of the candle power in about 700 localities throughout Great Britain. This mass of material I have tested and arranged in various forms, and ultimately in that of Table V., as the best I can devise for practical utility. It is altogether a table of averages, and requires little comment. The candle power I have found to range from 10 to 41 candles, the specific

gravities from ·342 to ·752, the number of cubic feet in 1 lb. of gas from 36·8 to 17·5, and the number of heat units per cubic foot of gas from 632 to 1257. These are the extreme ranges. But English gas differs widely from Scotch gas, and each admits of being classified apart. The distinction arises from the character of the coal used in the manufacture, the English employing common coal, with comparatively little admixture of cannel, while the Scotch employ largely the bituminous shales and cannel coals, with comparatively little admixture of common coal. These general distinctions are sufficiently familiar. In the results I find that English gas is used as low as 11-candle power, and rarely exceeds 20 candles, while Scotch gas is rarely found as low as 24 candles, and is in frequent use at 30 candles. From the table a practically useful approximation may be reached of the value of any gas of which the specific gravity is known, as the weight is an important index both of the illuminating and of the heating power.

TABLE V.

Candle Power ranging from	No. of Places where Candle Power is indicated.	No. of Analyses determining the Specific Gravity.	Average. Sp. Gr. Air = 1000 *	Average. Candle Power.	Average. Cubic Feet in 1 lb. Gas.	Average. Heat Units in 1 lb. Gas = 22,000 Units per lb.
10 to 12	14	11	·405	11·0	32·4	678
13 „ 16	360	33	·463	14·5	28·4	775
17 „ 20	192	14	·530	18·5	24·8	887
21 „ 24	20	8	·548	22·5	23·9	918
25 „ 28	116	11	·575	25·3	22·8	963
29 „ 32	64	10	·606	30·5	21·7	1015
33 „ 36	5	4	·640	34·5	20·5	1067
37 „ 40	3	3	·704	38·7	18·7	1174
	714	94	·559	24·4	24·2	909

Table VI., with which this inquiry closes, presents a general contrast of English and Scotch gas, in the leading characters of weight, bulk, illuminating and heating power. Extreme results are excluded from the table, and only the characteristics are embodied that are found in every-day manufacture and use.

TABLE VI.

	English Gas.	Scotch Gas.
Specific gravity practically ranges from . .	·342 to ·622	·525 to ·752
Candle power practically ranges from . . .	11 to 21	25 to 32
Cubic feet to 1 lb. gas practically ranges from	36·6 to 20	24 to 17
Units of heat per cubic foot of gas practically range from	632 to 1041	919 to 1294

The ground I have traversed embraces only the theoretical division of an inquiry into the heating power of coal gas. Another branch of the investigation involves a determination of the quantity of heat that practically is capable of being realized and utilized in the perfect combustion of coal gas. At present my space and time confine me to the statement that this heat may amount to very much more than the theoretical estimates which I have already shown to be based on shifting factors, and I have opened ground for reasonable belief that, with a better state of information on all the conditions involved, a higher ratio will come to be accepted. In practice, in the combustion of various fuels—notably in coal—much higher results are obtained in every-day use than would be admitted by theoretical estimates to be possible. In the improved methods for ensuring perfect combustion that are demonstrated in various boilers—in the hot-blast, in regenerative furnaces, not to speak of the great improvements in the methods of burning gas for illuminating purposes—we have illustrations and analogies that should satisfy the well-informed that there is an amount of heating power in coal gas fuel at present altogether unsuspected. But this division of the inquiry must be reserved for another opportunity.

[APPENDIX.]

To those who are familiar with analytical calculations, and the various methods through which they may be abbreviated, the detailed illustrations I am about to give will appear unnecessarily tedious. But there are some for whom they will be necessary, and for others convenient. Table IV. gives the key to the estimates of heating power of the coal gases computed in Table III. The following detailed calculations of the analyses of Mr. Ross and Mr. Harcourt are given with plainness and fulness, so that my criticisms may be easily followed.

* See note to Table V. in Appendix.

Note to Table I.—*Mr. Ross's Analysis.*

Vols. in 100 of Components of the Gas.		Grains of Weight in 1 Cubic Foot of Components.		Total Grains Weight in 100 Vols.		Units of Heat in 1 lb.		Total Grain Units of Heat in 100 Vols. of this Gas.
H . . . 51·80	×	39·048	=	2,022·686	×	61,524	=	124,443,783·446
CH_4 . . 35·26	×	312·384	=	11,014·659	×	23,616	=	260,122,186·944
C_2H_4 . 3·53	×	546·672	=	1,929·752	×	21,523	=	40,534,052·296
CO . . 8·95	×	546·672	=	4,892·714	×	4,295	=	21,014,206·638
N . . . 0·38	×	546·672	=	207·735		—		—
O . . . 0·08	×	624·768	=	49·980		—		—
100·00				20,117·527				446,114,179·324

The total grains in 100 volumes or cubic feet divided by 100 = 201·175 grains per cubic foot of gas.

The total grain units in 100 volumes divided by 100 and again by 7000 (grains in 1 lb.) = 637 units per cubic foot.

The total grain units in 100 volumes divided by 201·175 grains in a cubic foot = 22,126 units per pound.

7000 grains in 1 lb. divided by 201·175 grains in a cubic foot = 34·8 cubic feet per pound.

22,126 units per pound divided by 34·8 cubic feet = 637 units per cubic foot. 201·175 grains per cubic foot divided by 565·082 grains, the weight of 1 cubic foot of air at 32° Fahr. = ·356 sp. gr.

The estimate for specific gravity may be proved by the hydrogen numbers, which for the 100 volumes of the components of this gas are 515·20 (obtained by dividing the *molecular* weights by 2). Therefore 515·20 divided by 100 to give one volume, and again by 14·44 (the specific gravity of air in relation to hydrogen) = ·356 sp. gr.

[It has been represented to me, since the reading of my paper, that an illustration of the method of estimating the specific gravity of a gas from the "hydrogen numbers" would be much appreciated. I have pleasure in responding to the request, and will take for example the gas now under consideration :—

	Vols. in 100.		Molecular Weights.		Hydrogen Numbers for 100 Vols.
H	51·80	×	1	=	51·80
CH_4	35·26	×	8	=	282·08
C_2H_4	3·53	×	14	=	49·42
CO	8·95	×	14	=	125·30
N	0·38	×	14	=	5·32
O	0·08	×	16	=	1·28
	100·00				515·20

This number divided by 100 (to reduce to the weight of one volume) is = 5·152, again divided by 14·44 (to bring to a ratio with air as 1000 at 32° Fahr.) is = ·356 sp. gr. Air is 14·44 times heavier than hydrogen. The specific gravity multiplied by 565·082, the weight of 1 cubic foot of air at 32° Fahr., gives 201·169 grains as the weight of 1 cubic foot of gas; and 7000 grains in 1 lb., divided by 201·169, gives 34·8 as the number of cubic feet in 1 lb. of this gas. We may complete the estimate, including a near approach to accuracy in the heating power, by assuming my general average of 22,000 units per pound, and this number divided by 34·8 gives 632 units per cubic foot, or very nearly the value obtained by other very complicated and extensive calculations. In other respects the results differ to the extent only of some fractions of decimals from those obtained through more elaborate methods of computing. Such further explanation as may be felt necessary will be found in note to Table IV.]

If the components of this gas are separated into their elementary constituents, and their heats of combustion when separately burned are computed, a different result is brought out. By a rule-of-three calculation, the proportions of hydrogen and of carbon in the combustible combinations of the gas are found to be—

				Hydrogen.		Carbon.
51·80 cubic feet H contain grains of . . .				2,022	..	—
35·26	„	CH_4	„ . . .	2,753	..	8,260
3·53	„	C_2H_4	„ . . .	275	..	1,654
8·95	„	CO	„ . . .	—	..	2,096
				5,052		12,011
5,052 grains H multiplied by 61,524 units = 310,819,248						
12,011 „ C „ 14,544 „ = 174,687,984						
Total				485,507,232 grain units.		

This number divided by 201·175 grains in a cubic foot of gas = 24,112, as the heat units in 1 lb., or 693 in the cubic foot, capable of being evolved by the elements C and H when separately burned. Therefore, this gas evolves per pound of gas 1986 units, and per cubic foot 56 units *less* in the chemical combinations than the elements do when separately burned. (See No. 7 of Table III.)

Note to Table II.—*Mr. V. Harcourt's Analysis.*

The table shows that in 100 lbs. of this gas there are 58 lbs. carbon and 23 lbs. hydrogen; therefore—

C 58	×	14,544	=	843,552 lb. units.
H 23	×	61,524	=	1,415,052 ,,
Total.				2,258,604 lb. units,

These divided by 100 (the total weight of the gas) give 22,586 units per pound as the heat that would be evolved by the perfect combustion of the carbon and hydrogen when separately burned. Mr. Harcourt says 22,684, which is 98 units more than I make it; but the discrepancy arises, no doubt, from some difference in the multipliers used. The heats of combustion of these elements in their states of chemical combination as represented, present a very different result. Taking Mr. Harcourt's table, showing the composition and weights of the different gases, we find that—

	Pounds in 100.		Units per 1 lb.		Units per 100 lbs.
H	8·1	×	61,524		498,344·4
CH_4	52·9	×	23,616	=	1,249,286·4
C_2H_4	12·2	×	21,523	=	262,580·6
CO	13·8	×	4,295	=	59,271·0
CO_2	6·9		—		—
N	5·8		—		—
O	0·3		—		—
Total					2,069,482·4

Divided by 100, this gives 20,694 heat units per pound for the gas burned in its state of a mixture of chemical combinations.

To contrast the heating power estimated by weight against an estimate by volume, and to obtain the true volume, it is necessary to convert Mr. Harcourt's table thus—

Pounds in 100.		Grains in 1 lb.		Grains in 100 lbs.		Grains in 1 Cub. Ft.		Cub. Ft. 100 lbs.		
H .	8·1	×	7000	=	56,700	÷	39·048	=	1449·5	46·77
CH_4 .	52·9	×	7000		370,300	÷	312·384	=	1185·4	38·18
C_2H_4	12·2	×	7000	=	85,400	÷	546·672	=	156·2 ÷ 31·042	5·03
CO .	13·8	×	7000	=	96,600	÷	546·672	=	176·7	5·69
CO_2 .	6·9	×	7000	=	48,300	÷	859·056	=	56·2	1·81
N .	5·8	×	7000	=	40,600	÷	546·672	=	74·3	2·39
O .	0·3	×	7000	=	2,100	÷	624·768	=	3·4	0·10
	100·0				700,000				3104·2	99·97

In this calculation 100 lbs. of gas are resolved into 3104 cubic feet—Mr. Harcourt says "about 3000," but the process as detailed shows that 3104 is the true volume. The estimated heating power calculated for volumes, as shown in No. 4 of Table III., is 20,702 units per pound of gas, and 666 units per cubic foot.

We have now four estimates of the heating power of this gas, viz.—

1. Mr. Harcourt's estimate for *weight* of elements C and H, burned separately, 22,684 units per pound.
2. Dr. Adams's estimate for *weight* of elements C and H, burned separately, 22,586 units per pound.
3. Dr. Adams's estimate for *weight* of components, burned in combination, 20,694 units per pound.
4. Dr. Adams's estimate for *volume* of components, burned in combination, 20,702 units per pound.

The discrepancy between estimates 1 and 2 is trifling, and between 3 and 4 merely nominal. But between the first and the fourth estimate there is the enormous difference of 1982 units in 1 lb., and 90 units in one cubic foot, mainly caused by the difference in principle of our respective methods of computation.

There remains yet another mode in which this or any other table of coal gas analysis may be studied with advantage. Subjoined I present in parallel contrast the composition, weight, and heating power of one cubic foot of the gas under consideration. Column 1 gives the *elementary* constituents of the gas, and the binding brackets show where these have entered into the chemical combinations represented in columns 4 and 5; column 2 gives the grains of weight of each of the elementary substances contained in one cubic foot of the gas; column 3 shows the heat units which are capable of being evolved from the number of grains of these elements; column 4 gives the grains of weight of each chemical combination; and column 5 shows the heat units that are capable of being evolved by the combustion of these combinations. The weights of the 2nd and 4th columns are the same; but the total heat units in the 3rd and 5th columns differ very materially—a difference that can only be properly appreciated when it is multiplied by the number of cubic feet in 1 lb. of the gas, or by the customary 100 volumes in which gas is reckoned. The details bring out clearly the differences between the heating power of elementary substances and that of the combinations they form.

Composition and Heating Power of 1 *Cubic Foot of Coal Gas.*

Elementary Constituents of this Coal Gas.			Chemical Combinations and Elements in this Gas.	
1. Chemical Symbols.	2. Grains Weight of each Substance of 1 Cubic Foot.	3. Heat Units for each Substance in 1 Cubic Foot.	4. Grains Weight of each Gas in 1 Cubic Foot.	5. Heat Units for the Proportion of each Gas in 1 Cubic Foot.
H	18·26	160·51	18·26	160·51
C	89·43	185·85	119·27	402·37
H_4	29·82	262·06		
C_2	23·57	48·95	27·50	84·55
H_4	3·93	34·54		
C	13·33	27·09	31·11	19·09
O	17·78	—		
C	4·24	8·83	15·55	—
O_2	11·31	—		
N	13·06	—	13·06	—
O	0·62	—	0·62	—
	225·37	727·83	225·37	666·52

Note to Table III.

This table is constructed so plainly that "those who run may read." I have not thought it necessary to give all the sources from whence the analyses have been collected. In No. 8 I have thrown into one column six separate analyses (reported by Mr. Humpidge in the *Journal of the Chemical Society*, 1876), so that the entire table may be said to comprise 17 estimates; and as Nos. 5, 6, and 7 are published as representative or average samples, the entire series is fairly typical of English, and particularly of London gas. Regarding the candle power, I have given it as I find it, but incline to think the estimates somewhat rough, for in the case of one gas set down at 12 candles I have the assurance of the responsible official that it is really 16 candles, and from all I can gather it may be assumed that for this item a pretty liberal margin may be allowed.

Note to Table IV.

I have framed this table to facilitate my own calculations, and it may be better appreciated by others after a few words of explanation regarding the principle on which it is constructed.

The weights of equal volumes of different elementary bodies and compounds stand in a certain ratio to one another. This ratio is called the specific gravity, and, with a few exceptions, it is equal in the case of elementary bodies, as hydrogen, oxygen, or nitrogen, to the weight of one atom, and in the case of compounds to the weight of one molecule of the substance under consideration. For example, if the sp. gr. of 1 vol. of H is put down as = 1, atomic weight 1, the sp. gr. of 1 vol. of CH_4 is put down as = 8, molecular weight 16, the sp. gr. of 1 vol. of C_2H_4 is put down as = 14, molecular weight 28, and so on. By means of these data the weight in grains of any given volume of any of these gases can be calculated, if the weight of that volume of only one of the substances under consideration is known. Thus: One cubic foot of H weighs 39·048 grains; one cubic foot of CH_4 weighs 8 times 39·048 grains, and is 312·384; one cubic foot of C_2H_4 weighs 14 times 39·048 grains, and is 546·672; and so with other examples shown in col. 3 of Table IV.

Having thus a key to the weight in grains of the different gases, it is easy to calculate from analytical figures, which express the composition of a coal gas in volumes, the weight of the different constituents, thus—45·58 vols. or cubic feet of H, which weigh 39·048, multiplied by 45·58= 1779·8 grains; 39·90 vols. or cubic feet of CH_4, which weigh 312·384, multiplied by 34·90 = 10,902·2 grains, &c., &c.

Column 1 of the table gives the chemical symbol by which the constituents of coal gas are briefly expressed. Column 2 gives the atomic weight of the constituents, one-half of which is used as a multiplier for determining the weight or specific gravity of compounds, as already shown. Column 3, the weights (carefully calculated in grains) of one cubic foot of each constituent at 32° Fahr. Column 4, the heating power, expressed in units of 1 lb. of the substance, and it may be read: "One part by weight of the substance is capable of raising the temperature of the undernoted number of equal parts by weight of water through 1° Fahr." These "parts" may be grains or pounds, if so expressed. Columns 5, 6, 7, and 8 show the relative heating power of the different constituents, when applied to water and to air. And it should be borne in mind that 1 unit of heat that will raise 1 lb. of water through 1° Fahr. will raise above 4 lbs. of air through 1° Fahr. The method of computing the last four columns is as follows:—1 cubic foot of H weighs 39·048 grains, which multiplied by 61,524 grain units = 2,402,389·152, and this divided by 7000 grains (contained in 1 lb. avoirdupois) = 343·198 (representing pounds of water). 343·198 divided by ·238

(the specific heat of air, and equivalent to nearly a quarter of a unit) gives 1442 (representing pounds of air). 1442 multiplied by 12·387 (the number of cubic feet of air at 32° Fahr. in 1 lb.) gives 17,862 cubic feet of air raised 1°, or from 32° to 33° Fahr., or 1442 multiplied by 13·14 (the cubic feet of air at 62° Fahr. in 1 lb.) gives 18,948 cubic feet of air raised from 62° to 63° Fahr.

The formula may be briefly expressed (say for olefiant) thus: —

1 cubic foot C_2H_4 × 21,523 ÷ 7000 ÷ ·238 × 13·14 = 92,800 cubic feet raised 1° Fahr. from 62° Fahr.

Note to Table V.

In many instances the data from which I have averaged the specific gravities in this table indicate that these have been taken "air = 1000," by which I understand air at 0° C., or 32° Fahr., and barometer at 760 mm., or 29·922 inches of mercury, and this in modern laboratories are the customary temperature and pressure at which gases are estimated. But I do not think these distinctions have been in all cases properly understood or observed, and I know it is not unfrequent to estimate gases at 60° or 62° Fahr., sometimes to erroneously assume that this is equivalent to "air = 1000," and occasionally to give no indication whatever of the temperature or pressure assumed. The latter is a very reprehensible practice, confusing all estimates, and preventing accurate comparison of results. From intrinsic evidence I think that the average specific gravities in this table are all too high—that they have been assumed for 60° or 62° Fahr., and that they should be reduced by about 30 in each case—*e.g.*, ·463 should read ·433, and so on throughout the series.

I have already, in general terms, given my reasons for assuming an average estimate of 22,000 heat units per pound of gas. Among other methods by which I have reached this conclusion, I summarized results obtainable from Table III. in the following manner:—I noted that the analyses naturally resolved themselves into two groups, in the first of which the heat units were decidedly under 700 per cubic foot, and in the latter as decidedly above 700 per cubic foot. The first group comprised eight analyses, referring exclusively to common coal gas, and the second group comprised four analyses, of which two represented cannel gas and two a mixture of common coal and cannel. I arranged these two groups under letters A and B, in a manner that would bring out broadly and clearly their heating properties. A shows the heat units which are capable of being evolved from the combustion of *the components in their states of combination*, thus:—

Group 1.

Units per cubic foot	632 to 696.	Average =	662
Do. lb.	18,858 to 23,679.	Do.	20,962

Group 2.

Units per cubic foot	747 to 1,041.	Average =	896
Do. lb.	20,778 to 22,739.	Do.	21,671

General average, 21,316 units per pound.

B shows the heat units which are capable of being evolved from *the elementary constituents* of the gas when these are separately burned, thus:—

Group 1.

Units per cubic foot	686 to 765.	Average =	724
Do. lb.	20,736 to 26,492.	Do.	22,906

Group 2.

Units per cubic foot	811 to 1,114.	Average =	969
Do. lb.	22,238 to 24,693.	Do.	23,504

General average, 23,205 units per pound.

A represents a *minimum value*, and is too low, because based on the assumption that the combinations in the gas are all of the kind represented in a conventional analysis which takes no account of combinations having the extra calorific power I have referred to, and I have sufficiently shown the improbability of such being absent. Further, the average is unduly lowered through the preponderance of totals belonging to the lighter qualities of gas (group 1)—there being practically 17 against only 4 of the heavier qualities (group 2) to represent gases which range considerably above 25 candles, while only one of the four in group 2 is classed above 21 candles. It is clearly evident to me that an equal number of the heavy gases of group 2 would bring up the general average to a much higher figure, and several tentative calculations in which I have made hypothetical substitutions in various percentages of the heavy hydrocarbons have satisfied me on this point. B, on the other hand, shows too high results. Some additional heating value may be claimed from the large excess of combustible element to which at present no heating value is assigned. For there are reactions which occur during, and immediately after the first combustion, and which evolve an amount of heat not recognized under the conditions usually applied in the testing processes through which the calorific force of fuel is scientifically determined. These reactions are ensured in a methodical manner in the systems of combustion known as regenerative. But under ordinary conditions the amount of heating value due to this source must be very small and very variable. On the whole, I satisfied myself that 22,000 heat units per pound of gas is, for a general average, neither too low, nor yet unduly exaggerated.

Note to Table VI.

In this general contrast and average I have placed English and Scotch gas on a par at 22,000 units per pound. But Scotch gas is made largely from cannel coals, which are specially rich in the heavy hydrocarbons, and from which, even in the coal mine, and irrespective of manufacturing processes, there are evolved spontaneously large quantities of the heavy hydrocarbon gases. It may be held that, weight and volume being equal, the heating value of two gases should be equal. In a great measure this must be so; but for reasons tedious to expound in the present place, and having reference chiefly to the proportions of marsh gas, I have a well-assured conviction that the actual heat quantity and practical heating force of Scotch gas should be assumed at a higher ratio than English gas, even for equal weights.

The great difference in *weight*—and consequently in *bulk*—between English and Scotch gas is a consideration of highest importance in estimating the calorific power, or the total amount of heat obtainable from the perfect combustion of their constituents, as contrasted with the calorific intensity or pyrometric effect, which is the temperature obtained by the gaseous products of combustion. The first of these is constant for any particular composition, and does not vary with the method of combustion, assuming the combustion to be perfect. But although the quantity of heat which a gas will develop remains the same—provided the products of combustion are the same—the quality may greatly differ. The intensity of the heat within the flame, or area of combustion, will be the greater the more concentrated the fuel and the more rapid the combustion, *because the certain amount of heat in question is generated within a narrower space.* Relatively the English gas is not concentrated. The same quantity of combustible molecules that in English gas are sparsely diffused through a space of 30 cubic feet, are in Scotch gas compressed within 20 cubic feet. The flame of English gas is therefore characterized by comparative tenuity.

In the practical application of heat, it is only the portion of heat that is in excess over the temperature of the body to be heated that is really available heat; consequently, the higher the temperature the larger the proportion of serviceable heat to the whole heat generated. In short, the larger the quantity of heat evolved in a given space and time, the higher necessarily is the temperature, and the smaller is the area exposed to loss from radiation and other cooling influences; consequently, the greater is the amount of heat available for being communicated to the body that is being heated.

That an amount of heat equal to that of Scotch gas should be evolved by English gas within an equal time and space, it is absolutely necessary that the combustion of the latter should be hastened by the aid of the blowpipe, bellows, or other methods of inducing a more rapid delivery and combustion of the latter. A coal gas of light specific gravity and of expanded bulk is therefore not practically equal in heating power to a coal gas of heavier specific gravity, and therefore of more condensed volume.

Note on Differences in the Heats of Combustion of Elementary Bodies and of Chemical Compounds.

Marsh gas has already been cited. Acetylene affords another example, but of a converse result. In acetylene, which is an important constituent of coal gas, and is one of the fundamental hydrocarbons, the carbon and hydrogen which compose 1 lb. of the substance are capable of evolving 18,158 units of heat when separately estimated. But, in their state of combination as acetylene, 1 lb. of the substance is capable of evolving 21,500, or 3342 units more in number than are evolved from the elements individually estimated. Benzole is another notable instance of a much larger quantity of heat being evolved by the chemical combinations than by the separate elementary constituents.

Discussion.

Mr. W. Sugg said some of the figures in the latter of the two papers just read appeared rather peculiar. With regard to the quantity of hydrogen and olefiant gas given in Table III., the Manchester gas was stated to contain 45·58 volumes of hydrogen and 4·08 of olefiant gas; while the London gas was stated to contain 3·8 in one case, and 13 in another; 5·03, 3·67, 3·56, 3·53, and 7·02 in others. The gas

which appeared to be precisely the same had different numbers for the quantity of hydrogen in it. The London gas, it was well known, was nearly of the same composition throughout London. Unless, then, these tables had been taken at different times, he did not understand how there could be so great a difference in the constituent parts of the gas as appeared on the face of the table.

Mr. G. B. Irons (Gosport) said if Mr. Hartley was about to pursue his investigation with regard to calorimetry, and to produce a reliable calorimeter for use, he wished to mention that, having at different periods to carbonize Durham, or north country coal, and Somerset and Welsh, or west country coal, he found in the latter not only less heating power in the coke and coal, but also less heat from the gas; so much so, indeed, as to make a considerable impression on his mind at the time. He, too, had noticed the discrepancies to which Mr. Sugg had referred in the tables accompanying Dr. Adams's paper.

Mr. Denny Lane said it would be in the recollection of many present that a controversy arose some time ago between Dr. Adams and himself in the Journal of Gas Lighting on this very subject; and he must say, although not possessed of much apostolic zeal in this case, still he hailed a convert with very great joy. He now found that Dr. Adams had become a convert to the very views which he (Mr. Lane) then expressed. What he especially found fault with at the time was the statement by Dr. Adams showing his gas-stove to have been four or five times more efficient than any that had ever been produced before, and in support of this assertion it was alleged that using the unit of heat which Dr. Adams employed—namely, one cubic foot of air raised 1° Fahr.—the quantity of heat given by a cubic foot of ordinary coal gas was 51,000 units. He found in the tables accompanying the paper, for all gas of ordinary quality it averaged only about 22,000 to 23,000 units, so that he was very glad to find that, on further consideration, Dr. Adams had been a convert to his views on the subject. He (Mr. Lane) had intended to make what he believed would be an experiment giving a practical test of this subject, but had been prevented. His suggestion was this: During the summer period they all had gasholders to spare, and a simple practical experiment would be to fill one of these holders with air, to let the air pass through a chamber well lined to prevent loss of heat, and see what the temperature of the air was outside and inside the chamber. There would then be an experiment carried out on a large scale, and the temperature at the entrance of the apparatus, and at the outlet, could be actually measured; and there would besides be a perfect measurement of the capacity of the gasholder and the quantity passing from it. If proper care were taken with the experiment, the results should be very useful.

Mr. W. Foster, M.A., &c., asked if Mr. Lane appreciated the amount of heat that would be absorbed by the walls of such an apparatus. It appeared to him that in all questions of calorimetry the factor of correction for the apparatus in which the experiment was made was a most important matter; and unless Mr. Lane could give some assurance that the walls of his proposed chamber, through which the gas or the products of combustion were passing, did not absorb some heat, and an amount comparable to the total amount produced, there would be great danger of inaccuracy.

Mr. Denny Lane said there were two sources of loss of heat—one was that arising from the heat which would pass through the apparatus, and escape to the external air; and the other portion, that which was absorbed by the walls of the apparatus. He believed if the experiment were continued sufficiently long to allow the walls of the apparatus to come to a definite temperature, it would not have any influence. With regard to radiation, of course it would be a matter more or less of calculation. What had been done in similar cases in the very accurate experiments of Dr. Joule, on the thermal equivalent of heat, had been this: The temperature of the chamber which was to be estimated was at first a certain number of degrees below the surrounding air, and the experiment was continued until it came to a certain number of degrees above it; and it was supposed that by these means there was a balance of exchange—that at one time the walls of the chamber were taking from the external air a certain amount of heat, and at another time they were returning an equal quantity; that at one time there was positive radiation, and at another time negative, which balanced each other. He merely mentioned the experiment proposed as a practical experiment, not one of extreme scientific precision.

Mr. Hartley expressed his satisfaction at the elaborate paper and tables presented by Dr. Adams. The differences, he said, in the amount of the various constituents of London gas was doubtless due to the modes adopted for estimation. They all knew that in cannel gas the hydrocarbons condensable by bromine rose to 10, 12, and 15 per cent.; but such hydrocarbons were less dense than those contained in common coal gas. He was struck with Table V., where he found that the heating power of 10 to 12 candle gas was placed at 678 units, whereas his own estimation went to show that what was called 16-candle gas gave about 666 units by calculation. This was an inferred table, and he should think that Dr. Adams would find reason to modify it. As far as he (Mr. Hartley) was concerned, however, he was grateful for the publication of these documents. In so far as the denser light-yielding hydrocarbons were concerned, it did not seem to him that they could very much affect the heating power of the gas. In the case of London gas, the great difference in the effect produced by different gases lay almost entirely in the variation in the quantity of marsh gas present. He believed hydrogen was not an effective heater for general purposes; but marsh gas, on the other hand, was very valuable.

Mr. Wright said he did not feel competent to discuss many of the points that had been raised; but he thought Mr. Lane was under some misapprehension, for he was quite sure that Dr. Adams would not acknowledge himself a convert. If he remembered rightly, the 51,000 units which the Doctor claimed were by Mr. Lane himself shown to be equal to about 1100 standard units. In Dr. Adams's own paper he distinctly showed that some gases were capable of giving off at least 1200 units. He should say that, with regard to the publication of the results, it was done under some misapprehension. The tests were made, and had been confirmed with Glasgow gas; but he had not then made any experiments, and was not aware that there was such a difference between the heating power of English and Scotch gas as there appeared to be. As Dr. Adams showed, much greater heating power could be obtained by better apparatus. By the Birmingham gas and the Bunsen flame he had realized 610 units, and considerably more with improved apparatus. With the Scotch gas the heating power was much higher, and it would be reasonable to suppose the improved apparatus would give improved results with Scotch gas.

The President said the short discussion on the two papers read would not, he was sure, be taken as an indication of their appreciation of the labour of Mr. Hartley and Dr. Adams in preparing them. The subject of which they treated was somewhat abstruse and difficult, and not an easy one to discuss; but when they were printed in the Transactions of the Association they would be studied with considerable interest and profit.

(VI.)

THE ECONOMICS OF GAS MANAGEMENT.

By Mr. Henry Woodall, of Leeds.

I have long held the opinion that whatever importance may be attached to the engineering details of gas-works and manufacture, or however captivating prospective improvements connected therewith, there are at the present moment, waiting our command, certain simple commercial principles, generally little observed, which, if put into full operation, would distance all other considerations in the advantages they would confer. It shall be my endeavour to put before you, in as short a space as I can, a few of the most salient features of the policy which recommends itself to me, and without daring to hope that my views will meet with general acceptance, I have no doubt that many of us will derive some advantage from the discussion.

Of two great evils which beset gas consumers—extravagant engineering and Parliament—the latter inflicts the most widespread injury; the former, in occasional instances, the most acute. Here and there, I am sure, this observation will meet with an eloquent response in the breast of a manager, whose deserts can never be appreciated, simply because the works he manages were constructed by an engineer who, reckless as regards expenditure, has so heaped up the capital, that every-day economies are smothered by the burden of interest inexorably demanded. I have in my mind an instance in which the amount required to pay the statutory dividend exceeds 3s. per 1000 feet, in a locality where, upon a reasonable capital, the same rate of dividend might have been paid, and gas sold at about 2s. 6d. per 1000 feet. Now, under no ordinary conditions, as regards management or future engineering, can gas be sold at such a place at a reasonable price. About 2s. per 1000 feet has been wasted; and though the public may never know where to put the blame, it will stand

as an enduring reproach to the directors under whose management such engineering was permitted.

I am strongly of opinion that, in granting a common rate of dividend upon expenditure, whether large or small, without regard to its incidence upon the price of gas, Parliament has shown a strange disregard for the consumers' interests, and I should be glad if I could persuade gas managers generally that the future success of our undertakings may be in inverse proportion to the success achieved when we have induced Parliament to accede to our most ardent demands.

It is rarely that coal or any other item or group of items in our accounts influences the price of gas to the consumer so materially as the dividend; nor is there any item so difficult to move in his favour by the manager. And seeing with what certainty price and demand act and react upon each other, it should be the careful study of the manager to provide that any augmentation of plant should be accomplished, not only without swelling the amount of capital expenditure in relation to gas sold, but at a greatly reduced scale.

An ordinary rate of expenditure on capital account has been £600 per million feet of gas manufactured per annum; but at the present prices of materials it is not difficult to meet increased demands at a cost of £250 per million feet, or less than half the original expenditure. And, apart from price of materials, every year is witnessing an improvement in the situation in this respect, as I shall presently be able to show. The dividend on a capital of £600 per million feet, at an average rate of 8 per cent., costs practically 1s. per 1000. Now, supposing extensions of plant to be effected at a cost of £250 per million feet, and that the dividend on this is limited, as is now sometimes the case, to 5 per cent., then upon this the cost is only 3d. per 1000 feet, and there is thus a direct saving of 9d. per 1000 feet on all new business; and again, supposing an increase in the demand at the rate of 10 per cent., the price of gas may be reduced by ¾d. annually, until the charge for dividend falls to 5d. per 1000 or less.

Now, I know it will be contended that works, including mains and meters, cannot be laid down at £250 per million, for it may be shown that such a figure would only correspond to a capital of £50,000 for a make of a million feet per day in midwinter, and this may be a smaller rate of capital than exists. Well, I am not sure that works could not be constructed to-day within the price I have named; but supposing this were impossible, it is easy to show that for additional business my estimate is amply sufficient. Let any one consider that a million feet per annum is but the produce of one retort making 5000 cubic feet per day over a period of 200 days—the average time that a retort is in action during a year—and that consequently by every 5000 cubic feet that he improves the yield of his retort-house, he is saving capital to the extent of £40 (the cost of retorts per mouthpiece), and he will at once perceive how many ways there are in which economies of this kind may be effected. To dwell for a moment on this item, a retort-house containing 100 retorts, each producing 4000 cubic feet, and afterwards improved to 5000 cubic feet, is thereby increased in value by at least £1000, and if the remaining portion of the apparatus happens to be commensurate with this larger make, then the practical saving is double this amount.

Without going through the various portions of our plant which we generally know how to exact more work from when necessity demands, I will pass on to consider the gasholders, which cost, supposing their capacity to be equal to the greatest make of 24 hours, about 30 per cent. of our total expenditure in plant. The ways in which economies may be attained on this item are various. Single-lift holders may be converted into double-lifts, or double-lifts to treble-lifts, thus saving the necessity for new land and tanks; but better still is it, in my opinion, to limit the capacity to, say, 80 per cent. of the greatest day's supply, and to endeavour to equalize the demand throughout the hours of day and night. It is the happy tendency of our business to improve in this direction. During the day gas is being used for purposes too numerous to mention, and for the night we have to thank the promoters of the electric light for having created a taste for better street illumination, from which we cannot fail to reap considerable advantage. Our energetic President, supported as he has been by the most enterprising of Corporations, has shown us a brilliant example of how to shame the best efforts of the electrician, and it only remains to show at what a nominal cost such a display can be provided.

Perhaps even superior to the better lighting of public thoroughfares, in its economic aspect, is the warming of bedrooms throughout winter nights. People are rapidly coming to appreciate the luxury and benefit to health of an equable temperature, and when it is known that this can be conferred, by means of gas-fires, at the price of a glass of wine or thereabouts, we shall find that the costly disparity between the demand of one period of the 24 hours and another has been greatly diminished.

These latter observations have had reference to the saving to be effected by diminishing the ratio of holder capacity to the day's sale; for manifestly, if gas were in request at a constant rate, it might be sent to the consumers direct from the purifiers, and holders dispensed with altogether. And the nearer we approach this condition, the more we diminish the relative cost of plant, and the consumer derives a direct advantage by the amount of interest.

But however advantageous it may be to us to encourage the sale in winter, it is clearly more profitable to improve it in summer; for while a demand which is *pro ratâ* throughout the year—that is to say, which necessitates the erection of new works in the old proportion—can be met, as I have endeavoured to show, at a cost of 3d. per 1000 feet, even this sum is saved upon all business acquired during at least ten months which shall be in excess of the rate of increase in midwinter. Let me explain. Suppose the make of gas in midwinter to be 500,000 cubic feet, and the annual consumption 100 millions (the annual make divided by the daily make giving 200 as the quotient). Suppose again that next year you find that whilst the greatest daily make has continued at half a million, you have increased your annual make to 110 millions—your quotient for the year having improved to 220—you have clearly manufactured ten millions which has not required any extra plant, and the saving, where interest amounts to 1s. per 1000 feet, has been £500 on the year. I have introduced the quotient here simply to recommend it to those who have not already adopted it, as a ready method of recording, by a tabular number, progression or retrogression in our business, which is extra profitable as the figure is increased. Were it not that we require in all our apparatus some margin to admit of repairs, 365 would be our perfect number, for this would show a demand uniform throughout the year, and every portion of our plant fully employed.

I need not occupy your time by dwelling upon the smaller cost of mains and services in relation to an increased sale, for it is generally understood that a quadruple capacity can be acquired at only a twofold cost, and also that to improve the supply throughout a densely populated district, it is frequently only necessary to intersect the district, by a single main of large area; and thus where the original system of mains may have cost £200 per million feet, it is quite feasible to give a double supply at a rate not exceeding £50 per million feet.

I think it will be found generally that meters cost about 12 per cent. of the total expenditure in plant. Where meter-rents are charged—and I consider it to be decidedly to the advantage of seller and buyer alike that they should be charged—there is no manifest gain to a gas company upon a limiting of expenditure in this direction. But what is of equal moment to us is that the consumer profits the more, the more duty he extracts from the meter. If he burns 60,000 cubic feet of gas per annum, and his meter-rent is 5s., the meter costs 1d. per 1000 feet. If he consumes double this quantity, he has purchased his gas at an abatement of one halfpenny; and were he conscious of the economy he was effecting, he would be inclined to prize it at double its value, because he had secured it to himself by his unaided intelligence. And here I would predict that the day is near at hand when the manufacture of 2-light and 3-light meters will be very largely curtailed. Gas is now being used so profusely, and for such various purposes, that the smaller meters must speedily give place to larger ones in such numbers that those brought away will meet the demands of new property. I would advise managers to be very circumspect in ordering these smaller sizes, or it may happen that they will shortly find their stores encumbered with a costly stock for which there is no outlet. I confidently look forward to the 10-light meter supplanting the 3-light in thousands of cases in my own town within a period of three years.

To tilt at Parliament may be about as profitable as at windmills, and far less entertaining. Nevertheless it may be well to remark upon the serious consequences which have resulted to gas consumers from the want of some guiding principle in parliamentary legislation as it affects them. One company spending at the rate of £1000 per million feet, advised by its solicitor, asks for £100,000 of original capital to bear 10 per cent dividend, and gets it, at a cost of 2s. per 1000 feet to the consumer, and is removed beyond the pale of legislation for many years. In the same session another company, whose expenditure has been at the rate of £500

per million feet, asks for £20,000, and quickly spending it, comes again for capital, and is limited to 7 per cent., and in ten years the difference, commencing at 1s., has improved to 1s. 2d. in favour of the consumer. Well, there recently came a time when there appeared to be a probability of consistency in legislation, when it was enacted that new shares should be put up to auction, and the premiums obtained become capital without bearing interest—an excellent system, almost as good as to have left the previous legislation alone, and simply to have limited new shares to 5 per cent. At this juncture there sprang into existence the sliding scale, which, however much it may recommend itself at first blush to gas managers and proprietors, must in the long run prejudicially affect the interests of the former, if not of both, while there can be no question as to the burden it puts upon the gas consumer.

Previously to the introduction of the auction clauses, Parliament was limiting the dividends on new capital to 6 per cent. But as premiums on 10 per cent. capital generally ran as high as 100 per cent., it was evidently thought that by putting up shares to auction, capital would be raised at a charge to the consumer of only 5 per cent. Five per cent. then was considered by Parliament to be an adequate return upon gas investments. Look you now what follows. A company requiring capital applies for it under the new regulations. Its previous capital was £100,000. It needs to spend, perhaps at once, £10,000, 5 per cent. upon which amounts to £500, but by reducing the price of gas 4d. per 1000 feet, the company obtains the right to pay an extra 1 per cent., not only on the new £10,000, but also upon the original £100,000, and in this way new capital, which was denied more than 5 per cent. by Parliament, has become a charge upon the consumer to the extent of 16 per cent. Now I say it most advisedly to every manager present, that this sort of thing cannot be profitable either to him or to the consumer, and in the long run it may be found prejudicial to the interests of the proprietor himself, by retarding the growth of business, exciting cupidity, and inducing reprisals on the part of towns' authorities. I fully sympathize with the manager who, having a Bill before Parliament, seeks to secure to his employers the best return he can for their investment; but let him look all the facts in the face, and I venture to think he will see that the interests of seller and buyer are one, and that Mr. Sellers, of York, when he contented himself and his Company with a hard and fast 5 per cent., showed more wit than he received credit for at the time.

Having now touched upon the manner in which capital charges and rate of interest affect the price of gas, I will pass on to notice the incidence of certain charges in the revenue account. It is not my intention to occupy your time by discussing the many items in such an account severally, and so, for convenience, I will deal generally with a hypothetical case of gas at 3s. per 1000 feet. I will assume that such a price may be divided into three, as follows:—

Net cost of gas in the holder, after allowance for residuals .	1s. 0d.
Distribution, including repairs of meters, mains, and services, rates and taxes, collection, inspection, salaries, printing, &c.	1 0
Dividends	1 0
Total	3 0

In respect of the first section of the account, I have only to say that it does not fall within the province of this paper to deal in any way with economies in manufacture. The third section I have previously treated of. There is, however, a mine of wealth in the second section, for of all the items in the group there is scarcely one that is materially influenced by the quantity of gas supplied. Mains are laid down in the early career of a company, and ramify to the uttermost limits of supply, and the maintenance of these, as also of the service-pipes, costs no more whether gas flows through in a rapid stream or is stirred only by the leakage. The repairs of roadways are in relation to the mileage of mains, and are in no way affected by the sale of gas. It is as easy to take the index of a meter which has registered a million feet as if the quantity were only a hundred, and the collection of the larger account is frequently the simpler matter. Of this, too, I am positively certain, that salaries are by no means proportionate to the sale of gas. Repairs of meters, rates and taxes, office expenses, printing and stationery, are all of them items which are not affected relatively to the sale. Now, if I were to say that a doubling of the consumption would not increase the aggregate cost of this group of charges by more than 20 per cent., I should feel quite safe; but I will be liberal, and allow 25 per cent. And so there accrues a saving at the rate of 9d. per 1000 feet again, which, together with the previous saving of 9d. on capital, makes 1s. 6d. per 1000 feet on newly-acquired business. I have said nothing hitherto about leakage, which to many minds I know to be of vital consequence. Leakage I regard as being affected almost wholly by the length of mains and their condition, *plus* the adverse difference in the registration of meters, and hardly at all by the quantity of gas flowing through them. The gain, therefore, under this head, by doubling the consumption where the present ratio is 10 per cent., would be 5 per cent., which, taking the value of gas in the holder at 1s., would result in a saving of a little more than ½d. per 1000 feet. However, I will not take this item into account, and will deal only with the figure I have previously named—*i.e.*, 1s. 6d. Now, the question is how to make the best of our opportunities in regard to this large advantage. If we wait until the business doubles in the regular way, years go by, and the abatements we can make are small and unappreciated; the price, too, being high, competition is encouraged. If we divide the gains over all consumers alike, irrespective of profitable consumption, we give to the many at the cost of a few, and we limit the possibilities of our business in like proportion.

The incidence of commercial charges will form the subject of a paper by Mr. Warner, and therefore I will not dwell upon this part of my subject, but will give an illustration of the mode in which we can apply the advantage I have endeavoured to show that we possess. There is a competition in progress between electricity and gas for public lighting. The cost of gas is reckoned at its present market price. Electricity gives a more powerful light, which the vendors do not fail to take cognizance of when making their comparisons. It is only by so doing that they can hope to compete. Now, seeing at what a nominal price an extra quantity of gas can be made, and delivered to the public lamps, why should not the company say to the lighting authority: "If you want additional light, and will enter into a contract to consume a double supply of gas, we will charge you for the extra quantity at half the price you pay for your present consumption"? The gain by such an arrangement would be mutual, and it would only be securing to the lighting authority the advantage it would be fairly entitled to. There can be no doubt that if all classes of custom were expanded to the extent I have indicated, the price, where uniform, would be uniformly reduced. If, therefore, one section of our customers, clearly defined as are the lighting authorities, show a disposition to increase their demand, it is but rational, to my mind, that they should receive at once the fullest advantage we can concede. For my own part, I should rejoice to see the consumption of gas in the public lamps of Leeds increased from 3½ to 5 feet per hour, at a charge for the additional quantity not exceeding 1s. per 1000 feet. It is desirable, and in most instances absolutely necessary, that advances should be commenced with public lighting, for it is a common provision in our Acts of Parliament that the price of gas supplied to public lamps shall be not higher than the lowest price charged to any consumer. At present the public lamps are certainly not our best customers, but an additional supply thereto may be sold under most advantageous conditions, and in my own locality I have no hesitation in saying that 1s. per 1000 feet on the extra supply would yield a higher rate of profit than our present business taken in the gross.

What the possibilities of gas lighting are may perhaps best be explained by putting my own experience briefly in the concrete form. In 1876 the sale in Leeds amounted, in round numbers, to 800 millions, and the income from gas alone to £150,000. In 1881 the sale is 1200 millions, and the income £120,000; so that a favourable combination of circumstances has resulted in 400 millions of feet being given away, and £30,000 a year with it. Let it be granted that there is now an end to the special conditions under which these results were obtained, still I think I have shown that we have ample grounds for pursuing our business with a large-handed enterprise. I trust also that it will be quite patent that the electric light has really to compete with gas at less than half its present price, and also that schemes for supplying two qualities of gas through separate systems of mains can only result in disaster, if ever carried into practice. To adjust the price to the consumption, or to vary it with the character of the business, is not quite so easy in any other case as in that I have offered as an illustration of the working of the principle I am advocating; but as time goes on, and new markets present themselves, the difficulties of the situation will no doubt prove to be more apparent than real.

I dare not trespass upon your time to pass in review the host of minor considerations which fall within the range of my subject—such as meter-rents, discounts and differential charges, deposits, methods and times of collection, trading,

advertising, &c. These I shall be happy to deal with another time.

I have little doubt some present may be disposed to think that, in my earnestness on behalf of the gas consumer, I have forgotten that I am a gas manager. This, however, is far from being the case. I am proud of the office I hold, but I look for a much greater future for our industry than I could have anticipated only a few years ago. When I tell you that the increased manufacture of gas at Leeds, for the year just ending, approaches 140 millions, or 11 per cent., you will, I think, agree with me that the low price is likely to tax the best energies of the management; and though I say it, who have perhaps less reason to speak hopefully than many another, I still say that such development of our business must inevitably result in an improvement of the status of our profession.

(VII.)

THE INCIDENCE OF COMMERCIAL CHARGES IN THE SELLING PRICES OF GAS.

By Mr. W. J. Warner, of South Shields.

"Finance," it is satisfactory to see, takes its old place in what, it is to be hoped, will be our new constitution. The subject, or rather the matters for this subject, are less limited in number and scope now than they were in the earlier days of the Association. From parliamentary, legal, and official reports, facts and figures may be obtained which lay open to a great extent the working of many concerns. The scheduled form of accounts gives, too, the materials for comparison, roughly it may be, but still sufficient to enlarge the field for discussions on financial subjects. Our own proceedings have undoubtedly assisted in giving confidence in dealing with such subjects, and hence our broader views upon them.

There is still, however, the same spirit of prudence governing us in these matters that there was at the first general meeting of the Association, and there is still the same need of it. The esteemed President, Mr. T. Hawksley, at the first meeting said: "Now I feel that, though we cannot avoid dealing, to some considerable extent, with financial questions, as arising out of the subject of gas engineering and manufacture, there are certain aspects of that question, which, like rocks ahead, may prove our ruin if we enter upon them. . . . I think, therefore," he continues, "it is very desirable when these questions [rating] come before you, that you should not lay yourselves open to remark by attempting to go more into them than is absolutely necessary to convey information one to another; and that, as I understand it, is the object of the Association."

To this effect spoke many thoughtful members in the discussion on one of the papers last year, and amongst them Messrs. Livesey and Woodall, who have recently filled the presidential chair. The admirable paper of Mr. Livesey, in which he so boldly deals with the question of capital, and his late contribution to the Journal of Gas Lighting, also the paper of Mr. R. H. Jones on "Gasholder Capacity," are valuable additions to the financial matter of our business, though the two latter papers belong more to statistics.

A local association has addressed our Committee, I believe, upon the desirability of communicating with the British Association upon the subject of the formation of a distinct "section" for the consideration of gas questions. Without one word from me upon the value of such a suggestion, the dealing with which is not within my province, I would direct attention to the value to us, and to the desirability of the Association adopting the system of sectional work. Undoubtedly in an Association such as ours, most subjects are best discussed by the whole body of members; but there are, on the other hand, some matters that would be best prepared by a Sub-Committee, and discussed by a section of the Association. The work would be more carefully done, more reliable, and hence more valuable. And the one subject, above all others, to be so dealt with is that of finance, or statistics. Admitting that there is a desire for more facts, figures, and reliable data, and that there should be a considerable amount of prudence exercised in dealing with such questions, the responsibility should rest upon a responsible body in dealing with them. Unquestionably the feeling of the members, supported by some of the Presidents, has been averse to the adoption of a systematic publication by the Association of elaborated details of working. This feeling was decidedly expressed last year, though there were indications that this subject of finance, or statistics, if judiciously limited to well-defined bounds, would be of service if dealt with. If this meeting were to give an indication of approval of the subject being considered by the Committee, the same would doubtlessly deal with it in the usual careful, broad, and comprehensive manner.

There are two or three matters in connection with my subject which I think might well engage the attention of a committee or section, if the principle were adopted. I will take, first, Mr. Livesey's paper on "Capital and Revenue"—a most admirable paper, giving a standard and its relative proportions, and thus a fair measure, simple and well defined, for application to any individual case. Excellent as this paper is, and enhanced in value as it is by one of the best practical discussions recorded in our Transactions, yet it may be well supplemented by actual returns from our members, if not from the managers of the whole of the undertakings. The value of the rule given would thus be considerably enhanced for some purposes, if the measure of the average could be ascertained, and thus its true effect upon an average selling price be known. Though not appearing, in the revenue account, to affect the selling price, yet in many cases its influence is most oppressive. Not quite foreign to my subject is an allusion to the value of statistics which might be gathered under this head of capital, and that by which it has been, and is influenced.

In the draft form of statistics given by Mr. G. E. Stevenson last year, he would ask for "cost price of coal per ton delivered into works." But he gives the highest and lowest prices returned to him, in reply to circulars he sent out, as 19s. 4½d. and 9s. 6d. respectively. In commenting upon this, he says: "The results between which these comparisons are drawn are taken from works varying in size from 500 million feet to 10 million feet per annum, and situated in different parts of the kingdom. This fact is sufficient," he continues, "to account for the difference in the price of coal, which we may dismiss with the remark that every gas manager must judge for himself what coal will be most economical for him to use, having regard to the situation and circumstances in which his work is placed." I am not of an opinion that this matter should be so dismissed by us. As an Association, I think we might, with advantage to ourselves, examine this matter. Between 19s. and 9s. there is a great difference. A portion of this may come from the great difference in quantity, and the other from situation. The former is a private matter, with which we have nothing to do; but the latter may, at least to some extent, come fairly within the scope of our inquiries. The difference in cost from the difference in situation will come from carriage or dues, or both, and be levied by several public bodies. In the cost of coal from the Tyne to the Thames we have an instance of this in the river and other dues, and also the coal tax to the Corporation of the City of London. In other cases there may be disparity from the action of differential rates. This subject has excited considerable attention in the North, and it is one to which we may at least direct our attention. Here then, again, is good work for a statistical section to collect the rate of charges and dues and the cost of carriage per ton of coal; and, remembering that these charges do not affect the raw material only, but also the residuals, to include these also in such investigations. If by accident of position such rates, or dues, or charges are in excess of the current general charges, it appears scarcely equitable to consider them to be a part of the cost of the raw material, and also a further increase of cost, through the same cause, by a reduced net amount derivable from residuals.

To return to Mr. Hawksley's address at the first general meeting of the Association. He alludes to the question of rating, and while discouraging the going into such questions more deeply than is necessary to convey information, yet he says it will be well to have reference to, and seek to acquire some general understanding as to the principles upon which gas-works should be rated. This question, it may be said, is in as unsatisfactory a condition as it was at the time when that first address was delivered seventeen years ago; and the same words may be used almost now as were employed then—that there are those who are "ever busily engaged in seeking to rate profit instead of that which the Act of Parliament prescribes as the rateable subject—the hereditaments of the establishment." Though the alteration of the rates is felt in the selling price, yet there is something worse than the amount in some cases perhaps, and that is the disturbing influence upon the price. As an example, a company in which I have an interest reduced the price of gas last year; this was followed by an increase of the rates to the extent of nearly 1d. per 1000 feet. This is a serious matter, and I cannot but think that a controlling or a modifying influence might be exercised through the labours of a statistical section of the Association. Our esteemed friend, Mr. J. Paterson, when

President, alluded to this question in a very strong and forcible manner, and he gave a case in which he was engaged "where a re-valuation of the works for the relief of the poor was made in 1870, which resulted in an increase on the assessment of 28 per cent., being about 25 per cent. in excess of the fair assessable value. Not satisfied with such an increase, in 1873 a further addition of about 14 per cent. was added, simply upon the grounds, as stated by the Assessment Committee, that 'the profits of the Company had increased.'"

The subject of public lamps is one that has most seriously affected the selling price of gas. As the price to the private consumer is reduced, so do I find there is a desire to have the charges for the public lighting reduced, not upon the grounds that the lighting authorities are paying more than, or as much as the private consumer, but from a desire to maintain the old disastrous relative charges for public and private lighting. Here, again, a statistical section will find ample scope for its labours.

There is another matter that has an influence in many cases upon the selling price of gas; I will call it public convenience. Under this head would be placed a change of site or works as well as an alteration in the mode of working to suit public requirements. Both of these may only indirectly affect the selling price through capital. If, however, a higher illuminating power is exacted than the coal of the neighbourhood will give—assuming it will give a fair quality—then the selling price is directly affected through revenue. In the same way, if the residuals cannot be worked up on the works or in the immediate neighbourhood, there cannot be the same profit from them, and so again must the cost price suffer. Dead capital is another cause influencing the selling price, and may be a heavy burden where costly sites have to be purchased.

As much of what I have advanced is common to every commercial undertaking, it may be considered that all is likely to fall upon those carrying on an analogous business to our own. We may consider these, then, as commercial charges, and though it may be scarcely possible in many cases to ascertain their extent or influence, yet they must be felt in the selling price of gas. In the consideration of this price by those who are unacquainted with, or are antagonistic to our business, these matters are ignored, slurred over, or pooh-poohed; they, however, must be felt by every other established undertaking, as well as by our own, having an elaborated complex system of working from a common centre or centres.

Leaving the indirect for the actual commercial charges, we have them grouped together in the scheduled form of accounts D from No. 9, including rents, rates, taxes, management, secretary, clerks, collectors, and depreciation of leasehold property. The total amount of these several items forms a very large proportion of the charge for low-priced gas. I have not made any attempt to collect figures and compare them. In the Transactions of this Association, in the paper of Mr. Alfred Lass, the amount may be taken out, and it will be found to be 5·41d. per 1000 feet in a case given by him. This was in Lancashire; in the South of England, from a published report I have of the working, the amount is 5·40d.; and from another working, in the North of England, it amounts to 4·99d. In the last case the net amount realized was about 2s. 7¼d. These are all from moderate-sized works. Now, bearing in mind that this 2s. 7d. (5d. of which is absorbed by direct commercial charges) includes the cost of distribution and maintenance of distributing plant, much of which must be common to any other mode of lighting under a similar system to ours, and, further, that this price also includes maintenance of works, and dividends upon the capital invested in the same, we have a clearer view, I think, of our relative positions with the present rival schemes of lighting. Of course I exclude the marvellous, as set forth in a leader in the *Standard* not long since, by which the milkman is to supply in leaden boxes the light, heat, and power for the day's use.

The consideration of such subjects as I have ventured to touch upon may be of deeper value than the making of such comparisons; they should lead to such modification, if possible, as to improve our own working. The value of examining and considering the details of the cost and selling prices cannot be over-estimated. As an instance of the effect of consumption upon such charges (to which Mr. C. Woodall referred in his presidential address in 1878), I find that they go up from the 5d. per 1000 feet for the year to 19d. for the two summer quarters in one of the examples given. Here, then, we see the great value of every movement for encouraging consumption during the summer months, and the duty of those in charge of gas undertakings to assist in promoting and developing such schemes as have for their object the extended use of gas.

Discussion.

Mr. H. Peaty (Longport) said he had listened with very great pleasure to the two papers just read; but there was one point advocated by both gentlemen which he thought had been unduly pressed. A great argument for using gas for heating purposes was to be found in the fact that it would enable gas-works plant to be used in summer time, when otherwise it would be lying idle, and thus a saving of interest on capital would be effected. It had been stated that the production might be 500,000 feet per day in winter time, and it seemed to be assumed that it would remain constant while the summer consumption was considerably increased; but this was not altogether to be expected. If gas were to be used for heating purposes, the advantages would be more and more appreciated; and, therefore, it was more likely to be used for this purpose in winter, when the weather was cold, than in summer. The increment would thus come in winter more in proportion than in summer, which, although a good thing as far as extending the business of gas making was concerned, would not lead to a saving of interest on capital.

Mr. George Livesey said he, too, had listened with much pleasure to both papers. Mr. Warner must, however, forgive him if he did not say much about his; because, although he agreed with it all, there was a point raised by Mr. Woodall which he (Mr. Livesey) felt bound to deal with. With regard to the first part of Mr. Woodall's paper, he did not know that any more useful subject had been brought before the Association. It had been the misfortune of gas companies to work under a system that almost compelled them to waste their money in expensive, extravagant, and needless work; and he was very glad indeed to hear the opinion stated that for extending works £250 per million feet was sufficient. He believed they would be astonished at finding what could be done in reducing expenditure—especially capital expenditure. He could not, however, agree that 80 per cent. of storeage was sufficient. He used to work with this amount of holder capacity. He put up a holder which gave him about 95 per cent., and worked on until it was reduced to 70 or 65 per cent.; and then he would go on and get up again to nearly 100 per cent. But during the last few years they had gone beyond 100 to 120 per cent., and his experience went to show that it was a great advantage to have a large excess of gasholder capacity. For instance, if difficulties arose with the workmen, it had a strong influence on the stokers to see that the gasholders were full. At the time of the great London strike, the question whether the gasholders were full or empty had very much to do with whether the men were going to turn out or not. If they saw them full they said it was no use striking. He found, moreover, that with a large amount of storeage there was a greater latitude in working the retorts; they could be kept up or let down with greater facility in spring-time or autumn than if the manager was rather closely pinched for storeage. So that, although there was an expenditure of capital on this heading, he (Mr. Livesey) should certainly say it was judicious. Then came another point as to the expense of gasholders. He had heard of gasholders being erected for £30 per 1000 feet; and it used to be considered that £20 was a very fair price. He remembered once, when his friend was in a committee-room of the House of Commons, and Mr. Hawksley was under examination, and there was some question about a gasholder of Mr. Woodall's costing so small an amount as £10 or £12 per 1000 feet, Mr. Hawksley was asked the question: "'Should you be surprised to hear' of a gasholder only costing £12 per 1000 feet?" Mr. Hawksley's characteristic reply was, "Gossamer gasholders." However, he believed the "gossamer" gasholders had stood, and were standing at the present time. Another thing he (Mr. Livesey) would urge was: Have plenty of storeage, but endeavour to erect the gasholders at the smallest possible cost. He was bound to say that here, he thought, there was room for improvement; they had been too much in the habit of allowing gasholder builders to design gasholders, though in fairness to them it should be said that they had rendered very valuable assistance to engineers. He believed that gasholders could be constructed, which would not fall down or blow away, at a cost not exceeding £10 per 1000 feet. Of course he referred to large gasholders, not to small ones. Then Mr. Woodall came to the question of the auction clauses and sliding scale. As a gas shareholder he (Mr. Livesey) never liked the auction clauses, because fresh allotments of capital at par were very pleasant; but when he was asked the question by Mr. Farrer, of the Board of Trade, he was bound to say they were fair, and were working well.

With the monopoly which gas companies possessed, it was fair to the public that all new capital required should be sold by auction—at any rate that the shareholders should not put a large bonus into their pockets by the premiums realized. He did not think that ordinary capital could now be raised at 5 per cent. No doubt the electric light "scare" had had an influence on the value of gas shares. The Chartered "A" stock before the first scare on the electric light question was selling at £220; it then dropped to £190; then came the great scare, when it dropped to £150 or £160, and since then it had not quite reached £190. He thought under the present circumstances it could not very well be issued at a lower rate than 6 per cent., and he doubted whether a much better plan than the auction system, when combined with the sliding scale, could be adopted. Now came the great point on which he differed from Mr. Woodall. He granted at once that he had pitched upon the objectionable feature of the sliding scale—that it did tend to an increased charge for capital on the gas made—but he did not tell them of the counteracting principle which underlay the sliding scale. He (Mr. Livesey) could not, in the absence of it, see what inducement there was for gas managers to economize, and rack their brains to reduce expenditure on capital, and to economize in the matter of revenue. It might be said that the electric light was a competitor, and was putting them on their mettle; but he rather doubted whether it would be more than a passing thing—it had not affected him in any way; but the sliding scale had affected him very much as a gas manager. He said unhesitatingly that, although by the adoption of the sliding scale the dividend was increased, and thereby the cost per 1000 feet to the consumer was increased to that extent, it was counterbalanced, and more than counterbalanced, by the strong inducement gas companies had to reduce prices. He could say from experience that directors and managers of gas companies were now acting on the strictly commercial principle of endeavouring to buy in the cheapest market, and to save in every particular; to economize to such an extent in the cost of coal, in the working, in the expenditure of capital, and in all other departments, that he felt perfectly certain it far more than counteracted the objection which Mr. Woodall had pointed out. Moreover, the sliding scale had followed a system which had been described as the worst which could have possibly been invented for the gas interest—the worst for the consumer and the worst for the gas producer. The old system secured 10 per cent. dividend—it did so practically, because the maximum price was more than sufficient, under all circumstances, to enable full dividends to be paid, and they had no inducement, therefore, to economize; whereas under the present system the strongest inducement was brought to bear, and although it had only been in operation three or four years, he was satisfied that a greater reduction in price had taken place in those companies which had been under its operation during this time than would ever have taken place under the old system. He believed, notwithstanding that they were handicapped in this way by a slightly increased dividend, they could show it was a most direct benefit to the consumers. The Board of Trade in 1876 said there were no means of controlling the expenditure of gas companies; the manufacture of gas was entirely in their hands, and it must be made to their interest to reduce the price, if the consumer was to be served at a low figure. No fault was to be found with the directors of gas companies, but the system placed them at a disadvantage. The old system was a system of protection; they were protected in every way, and therefore they were resting on their oars. Now they were promoting their own interest in forwarding that of the consumers, and he believed it would be seen that the public would largely profit by it. He could not quite agree with his friend Mr. Woodall in saying that they should charge half price for the additional gas consumed in the public lamps, because he could not see why other consumers—railway companies, for instance—should not ask for the same privilege. Of course it would become known that gas was given to the public lamps at the lower rate, and such large consumers would ask why they also should not have it. He admitted there was a good deal in what Mr. Woodall said about inducing public authorities to increase the quantity of gas used for lighting the streets; still the fairest thing would be to charge the same, or very nearly the same price. The only thing he would concede to the public bodies was a 5 per cent. discount on condition of prompt payment; and this he would do on these grounds: That they were large consumers, that there was no chance of bad debts and no cost of collection; and adding together bad debts, cost of collection, and office expenses, it cost 5 per cent. less to supply public bodies and railway companies than it did to supply the ordinary consumer. He would, however, make no further concession to them.

Mr. Alfred Penny said that after Mr. Livesey had spoken there was very little left for anybody else to say; but what he wished to mention was this: Mr. Woodall had given some instances of the very large sum which fell under the charge of dividend—of course he alluded to some of the older companies; but the important fact had been overlooked that these old companies had existed time out of mind (long before the recollection of many of the gentlemen present), and they had had to encounter all kinds of difficulties at the commencement of their undertakings, arising principally from the want of knowledge as to the best mode of constructing their works and apparatus. In many of these cases where the charge for dividend stood very high, it was rendered unavoidable by large expenditure upon the works—viz., by the destruction of old but costly apparatus, and the reconstruction of the same on more modern principles; and this, in some cases, was repeated more than once. It might be said that this kind of expenditure ought to be paid for principally out of revenue. No doubt it should have been; but he feared it had not. His experience—having had to examine many companies' accounts when they came before Parliament—revealed this state of things, that while the *proper* normal expenditure for ordinary repairs and maintenance was 6d. or 7d. per 1000 feet of gas sold, the *actual* outlay under this head was sometimes only 3d. or 4d., they having left out of the accounts the item for reconstruction and renewals. In many companies' accounts the important item of maintenance was represented by comparatively small sums expended for putting in fresh retorts, &c., and they paid out of capital the charges, which ought to have been provided by revenue, for reconstructing and renewing their works and apparatus; and this was one of the great causes why many old companies were overloaded with capital, and required so large a sum to pay their statutory dividends. As a rule they were getting wiser now, and companies were spending such sums out of revenue account as would not only pay all the ordinary charges for repairs, but would be sufficient to reconstruct that which they had necessarily to destroy. In companies' accounts generally, an old and perhaps costly gasholder or an old set of purifiers, &c., stood in the capital account for the sums which they originally cost; and it had been too much the custom to pull down old plant and sell it for what it would fetch, merely carrying the sum received to the credit of capital account. But this was an improper mode of dealing with such matters, and one which entailed, in the future, a larger charge upon capital than it was entitled to bear, and the appropriation of a sum for dividend which was not fairly earned. He believed, however, that this method was no longer the rule, but the exception, and he hoped that the grand future Mr. Woodall had prognosticated—when gas would be sold at the lowest possible price, and gas companies, by using judicious economy, would still prosper—would some day be realized. No one had done more to bring this about than Mr. Livesey; the Company which this gentleman represented had the merit of selling gas in the Metropolis at a lower price than any of its competitors; and he agreed with every word Mr. Livesey had said about the inducement to reduce the price of gas which the sliding scale had given to the companies who had adopted it, as they could not get increased dividends without giving to the consumers quite three times as much advantage as they obtained themselves. These observations, he (Mr. Penny) added, were not intended to deny or excuse the evils arising from an unduly heavy capital account, which Mr. Woodall had observed upon in his excellent paper, but rather to explain some of the causes which had produced such a condition of things.

Mr. A. C. Fraser (Bolton) said that in the question of gas storeage gas managers must necessarily at all times be guided by local circumstances. They ought to have storeage capacity somewhat in excess of one day's maximum consumption, and anything under this amount would not be safe, for if there came two or three consecutive days of fog they would have to go on all day firing up additional retorts, and bring the holders down from their normal condition to 50 per cent. stocks, which was an extravagant way of working; whereas if they had an adequate storeage they would save fuel, &c., firing up the retorts hastily. He did not find that over 100 per cent. was at all more storeage capacity than was required. As to the question of erecting plant at the rate of £250 per million feet, he did not believe in it; it was possible to put up "jerry" plant which would soon become worn out; but he believed the more substantial that plant was erected the better. It was possible to adopt the

"penny wise and pound foolish" policy in this important matter. As to the price at which gas could be produced, it must of necessity depend to a great extent on the price at which the coal and cannel used were being supplied.

Mr. C. Eastwood (Dewsbury) wished to make an observation with regard to differential charges for public lighting. Mr. Woodall suggested that additional gas supplied to lamps should be charged for at half the ordinary price, while Mr. Livesey said he would make no difference between the two classes of consumers beyond 5 per cent. discount for cash. It might be of interest to mention to the meeting, as he represented a Corporation, that the feeling against differential charges was not experienced amongst the ratepayers themselves. At Batley they had been accustomed for a long time to charge for public lamps, including lamplighters' wages and repairs, 1s. a year per lamp—a nominal charge, of course—and yet up to the present time not a single ratepayer or gas consumer, large or small, had objected to the arrangement. He therefore thought that gas companies might be satisfied that if they made a distinction in dealing with corporate bodies, ratepayers and gas consumers would not complain.

Mr. G. B. Irons (Gosport) agreed in the objections urged to the sliding scale, and thought Mr. Livesey had failed to substantiate his views in support of it by the points he brought forward. He thought it would be found that, after the passing of the Gas-Works Clauses Act of 1847, greater reductions took place in the price of gas than had taken place under the "sliding scale" clauses, taking into consideration that at present all the raw materials for gas manufacture and distribution were at about the lowest point. Again, as to there being no inducement to reduce prices under the Act of 1847, he would remind those who were under this Act of the very potent power placed in the Court of Quarter Sessions. If any of them were once brought before such a Court, it was not a question of what they could supply gas at, but what the Court would compel them to supply it at. If they had been making excessive profits and supplying gas at 4s. 6d. per 1000 feet, and the Court of Quarter Sessions said they should supply it at 2s. 6d., they might, in the result, have to go without a dividend, and they could not help themselves.

Mr. G. E. Stevenson (Peterborough) was not aware, until Mr. Irons made the remark, that any Court of Quarter Sessions had the power of Parliament, and that it could legislate for gas companies as to the dividend they should have, and the price they should charge for gas. He understood Mr. Irons to mean that supposing a gas company was making a great excess of profit over and above what was necessary to pay the maximum dividend allowed by Act of Parliament, the Court of Quarter Sessions could exercise its right, and compel the company to reduce its price within reasonable limits; and, if so, he quite agreed with him. But this had not proved in the past to be a satisfactory check against excessive charges, and certainly not a check against the excessive expenditure of capital, because with this aspect of the question the Court of Quarter Sessions had had very very little to do in such rare cases as had come under its notice. Provided the gas company did not pay dividends in excess of its legal right, and did not accumulate profits over and above what it had a right to place to the reserve-fund, he could not see what the Court could do in the matter. Mr. Livesey had stated as clearly as could be the value of the sliding scale. Mr. Penny had mentioned that for every sum of money which went to increase the dividend at least three times as much was remitted to the consumers in the price of gas, and this had to be allowed first of all before the excess dividend was paid. This point came out clearly in Mr. Livesey's evidence this year before the Parliamentary Committee on the South Metropolitan Company's Bill. He there showed that the sliding scale worked to the advantage of the gas consumer; the Metropolitan Board were entirely disarmed; and the Bill passed without any alteration in the standard price of gas. There was one point in Mr. Woodall's paper which had not yet been remarked upon, but which was worthy of notice. He gave a hypothetical case of gas being sold at 3s. per 1000 feet, and estimated the cost in the holder of manufacturing this quantity at 1s., the cost of distribution and management 1s., and the dividend 1s.; and then he went on to say that by doubling the consumption of gas the distribution and management charges would be reduced 9d. per 1000 feet. If he (Mr. Stevenson) had understood aright, it seemed to him that this was a very sanguine view of affairs. There was no question that the cost of distribution and management did not increase in the same ratio as the consumption; but it certainly did increase, and by the time that the consumption was doubled, there must of necessity be a very considerable increase in the cost of distribution and management. Then there was the question of leakage and laying of mains; for mains once laid would not last for ever. Not only must they be enlarged, and thus cause the actual leakage to increase; but it was not conceivable that the consumption of gas in any town could be anything like doubled, without an extension of mains to outlying districts not before supplied.

Mr. Denny Lane wished to make one observation on the proposal of Mr. Woodall to reduce the charge for gas supplied to public lamps, which he believed was utterly unsound as a commercial principle, and founded on a fallacy which had deceived a great number of people. In any well-conducted business wholesale purchasers could always buy at a lower price than retail purchasers, and it was a very common fallacy to suppose that a corporation was a wholesale purchaser. This was, however, altogether erroneous. He had had occasion to look into the question lately, and he found that the average consumption of each public lamp was not more than one-third or one-fourth that of each private consumer, and consequently there was more leakage from the great number of lamp services, each of which supplied only one-fourth of the gas consumed by each private customer. He should say, therefore, that a corporation was only a large aggregate of small consumers, and therefore he agreed with the doctrine laid down, that the only concession which should be made to a corporation was that which arose from the certainty of payment, the absence of bad debts, and the facility of collection. He had been engaged in some controversy with a corporation on this point, and had demonstrated that the whole of these considerations could not amount, on the outside, to more than 2 per cent.; but at the same time the company proposed to offer the corporation a discount of 4 per cent. The end of the discussion was that when the case was fully considered, the corporation accepted the offer.

Mr. Charles Hawksley said he concurred entirely in the remark which had fallen from Mr. Denny Lane, that a corporation was an aggregate of small consumers, and ought not to be regarded as a large consumer, except in respect to the one particular, that it paid its bill in one large sum instead of in a number of small sums. With regard to the extravagance which had been stated to have existed on the part of many gas companies, he must entirely dissent from the view expressed, as in all the works which had come before him at one time or another he did not think he could recall a single instance in which capital had been recklessly laid out. But there had been extravagance from another point of view, which had in many cases arisen from a false economy on the part of directors of gas companies. They had frequently been timorous in their action, and had made a small extension when they ought to have made a great one; providing only for an extension to carry them over two or three years, when they ought to have provided for an extension to carry them over a much longer period. This was because they had not possessed sufficient faith in the elasticity of their own undertakings. Consequently the extravagance he referred to had arisen, not from the wish to make a useless outlay of capital, but rather from the desire to curtail expenditure, and keep down the capital account to the lowest possible point. Referring to the subject of light gasholders, he must say he still remained of the opinion to which Mr. Livesey alluded in his remarks. Exceedingly light gasholders might answer the purpose in the first instance, but he did not think in the end they would prove economical. He was aware there was a great difference of opinion on this point amongst engineers, but he certainly was of opinion that it was desirable to erect a gasholder which would last, and be sufficiently strong to enable the gas manager to sleep comfortably in his bed. He had known a case where, during a gale of wind, the manager had to get up in the middle of the night, and put on a number of men to hold the gasholder in its place. When considering the effect of the sliding scale, there was one point which was rather apt to be overlooked, and this was that it tended to make companies do only that which they were obliged to do to conform to the requirements of their Acts of Parliament, instead of improving the quality of the article they supplied, so as to make it superior to the standard below which they were not permitted to descend. In the desire to reduce the price, they kept down the quality of the article to the level of the requirements of Parliament, instead of striving to improve it both with regard to illuminating power and purity. While on this point, he would call attention to the comparison of prices which was very frequently made between the supply of one town and that of another, and point out that a comparison of prices *merely*

was really of no use whatever. In comparing what gas was given in different towns for the money charged, purity and illuminating power ought to be taken into consideration; otherwise the price of a fourth-rate article might be compared with that of a first-rate article. With regard to the statistics which Mr. Warner suggested should be collected, he feared there would be such difficulty in reducing all the circumstances of each case to one common measure, that the statistics would fail to be of much value when obtained. There were so many considerations to be taken into account that it was almost impossible to reduce them to any common datum. Amongst other things, there was the expenditure of capital incurred at their starting by the gas companies which had originally borne the brunt of introducing the system of lighting by gas.

Alderman Moscrop (Bolton) said he was glad to hear Mr. Woodall lay down the principle that sound commercial policy ought to guide the proceedings of corporations. Granted, he said, that corporations had a right to become trading communities so far as regarded the manufacture of gas, he thought the inference was that they ought to charge not only the cost price of the article produced, but a reasonable price for the production of so important an article, and the ratepayers had a right to have 5 or 10 per cent. profit upon the capital invested.

The President said this point was rather beyond the scope of the question under discussion, and he must ask that new matter be not introduced.

Alderman Moscrop: I accept your ruling, Sir, very willingly.

Mr. Henry Woodall, in reply, desired to thank the meeting for the courteous way in which his paper had been received. Mr. Peaty had, he said, objected that he had taken the 500,000 feet as a constant quantity, and based his calculations on this quantity remaining constant. But when Mr. Peaty came to read the paper he would see that he had not done so. He simply said that supposing the quantity of gas to remain constant during the winter, whilst the summer consumption increased, they would have with such a state of affairs the advantage of 3d. per 1000 feet in excess of what he calculated upon. They would have the advantage of 1s. per 1000 feet, under such circumstances, compared with 9d., which was the only figure he had used. Mr. Livesey objected that 80 per cent. of gasholder room was not sufficient. He did not care much to argue on behalf of the 80 per cent., because he knew the percentage must vary with the conditions of the neighbourhood being supplied. He only suggested that it should be the study of gas managers to alter these conditions as much as was in their power, so as to make the quantity of gas delivered throughout the 24 hours as equable as possible, because the nearer they could reach this condition the more they could limit the gasholder capacity required. Mr. Livesey considered that a large gasholder was an advantage in dealing with the workmen, because, by having large storeage, a manager could bring his men into better subordination; but his (Mr. Woodall's) opinion was that in this respect a machine stoker was of far greater advantage, and would not cost anything like so much, even if it were kept idle. He would also point out that the reduction of Sunday labour must inevitably tend to limit the necessity for increased storeage; and he thought before long they would all be coming round to the view of the case, that a reduction of Sunday labour was necessary. When this was accomplished, the number of retorts at work throughout the week would be more proportionate to the week-day's demand, and thereby again they would limit the necessity for gasholder room. Mr. Livesey naturally upheld the sliding scale; but he confessed that he was a large shareholder, and that it touched him very nearly. For the first time in his experience of him he found Mr. Livesey in a very contradictory position. For many years past they had known Mr. Livesey professionally as one of the most honourable men in connection with their business; they had known him as one of the greatest enthusiasts in the direction of economizing, in all directions, in favour of the consumer; and now he came forward and wished them to forget his enthusiasm in the past, and to believe that for a paltry consideration of 1 per cent. added to his dividend he was going to forget his past work, and put an amount of enterprise, with increasing years, into the business which he had not done in days past. With all deference to Mr. Livesey, he (Mr. Woodall) did not believe it was possible for him to do more in the future than he had done in the past. Mr. Livesey said that the price of gas had been largely reduced consequent upon the introduction of the sliding scale; but he (Mr. Woodall) would ask those present to bear in mind that never in the history of gas undertakings had the conditions of manufacture been so favourable to a low price for gas as at present. He did not wish to say anything at all to the disparagement of what might be going on; but he thought it very possible that many of them, in anticipation of applying to Parliament, had postponed any reduction of price which they might have made had it not been for the expectation of coming very soon under the sliding scale. He would urge on those who were managing gas-works in provincial towns not of very great capacity, that by the introduction of this system they were instituting an element almost of gambling. It might result in some practices which were not altogether what they should like. It was quite possible for an adventurer to purchase a number of shares in an undertaking, get himself placed on the board of directors, and so to manœuvre the concerns of the company as to "bull" and "bear" the market, to his personal advantage, and they must be individually losers by any such arrangement as this. The price of gas might be reduced by expenditure being limited throughout the year, and consequent high premiums paid by proprietors, upon which they would look for the increased dividends in perpetuity. In course of time they might have to put a larger amount of expenditure into their operations, and when the dividend came down they would have to bear the blame. Mr. Livesey also objected that the price of gas should not be reduced to town authorities below 5 per cent. of the charge to ordinary consumers, and he (Mr. Woodall) might answer a number of others who had objected to his views with regard to public lighting at the same time. He had clearly laid it down that public lighting was not the most profitable part of the business. He was aware that each public lamp was a separate consumer, and upon the gas consumed he found in his own experience they only received about half the income they received from the average private individual. But they were in this awkward condition, that they were obliged to sell gas to the town authorities at the lowest price at which they could sell to any consumer; and therefore they could not make an abatement to any other parties until they had first made a concession to the town authorities. All he proposed was that the extra quantity of gas supplied to town authorities should be sold at this lower price. If their consumption at the present moment was 20,000 feet per annum in each public lamp, and 30,000 feet were given, there would be no extra leakage on the quantity supplied, the mileage of the mains would be the same, the services and the collection would be the same—everything continued the same, and the manufacturing price only had to be charged *plus* the interest on the necessary expenditure in plant required to meet the increase. Mr. Penny contended that the heavy charges on capital, to which he referred, appertained to old plant; but the cases he had in mind were amongst the newest of plant, or rather he should say a case of the highest cost was that of a gas-works erected only about ten years ago. Things of this sort were going on to-day, and they needed to be checked by the best energies of the manager. Mr. Fraser made a remark about plant which was not erected sufficiently strong. He (Mr. Woodall) should certainly have everything sufficiently strong, but when he advocated strength it did not follow that he meant lavish expenditure. Mr. Eastwood referred to the conduct of the Batley Corporation, who made only a nominal charge for public lamps. He (Mr. Woodall) thought nothing could be more unfair than such an arrangement. It could not be an advantage to the gas consumer—in fact, it was a tax upon him; and could not be an advantage to the community, because it prevented the use of gas, and the consequent profit on increased consumption. Mr. Stevenson objected to his taking 9d., as the profit upon distribution charges on the extra consumption, as too high a figure; but he could say that in making his estimates from year to year he had not advanced the rate beyond 25 per cent. on the estimated increase in business, and he found that they did save at about this rate. One member also objected that leakage would form a very considerable charge on the increased business, and spoke of more leakage from larger mains. His experience was that the leakage was not from the large mains, and that as the consumption was increased thicker pipes were used, the mains were better laid, and less liable to be broken by road traffic, and various other causes; and consequently there was an actual reduction in the leakage in bulk, while, as a matter of course, the ratio was reduced in proportion to the increase of gas supplied.

Mr. Warner said he had only two matters to refer to, one of which was with regard to the charge for public lighting. He thought some little allowance should be made to the public authorities, because there was one point, which had

an influence, that had not been glanced at. This was that there was no risk of bad debts. On the other hand, if the consumption was to be increased by the introduction of larger burners, they would sustain a greater loss from leakage. His own experience was that from time to time, in back streets and low neighbourhoods, a considerable number of lamps were found turned on, and the gas escaping for perhaps sixteen out of the twenty-four hours. Then again there was another loss from the accidental knocking down of the lamp-pillars, and the gas escaping for some time from the open end of the broken pipe. With reference to Mr. Hawksley's remarks on statistics, he would simply say this, that there were some statistics he thought they might have with considerable advantage to themselves. As an instance of the want of statistics, it was not possible to obtain an account of the actual amount of capital invested in gas undertakings in the Kingdom. So again with regard to rating, and the expense of this per 1000 feet of gas supplied. He did not think there would be very much difference of opinion as to the value of such figures as these. If there was a statistical section of the Association they would consider what information should be asked for, and the members of the profession would all be safe in the hands of such a committee.

The PRESIDENT said Mr. Warner's paper had dealt with matters which were highly suggestive, but at the same time it was not unnatural that the discussion which had arisen should turn almost exclusively on the somewhat controversial matter introduced by Mr. Woodall. He could not but compliment this gentleman on his very able paper, and if time had not been so limited, he (the President) should have been inclined himself to have spoken on many matters which he had touched upon; for, although there were some points as to which he cordially agreed with him, there were others from which he most sincerely differed. Mr. Woodall started with the proposition that gas consumers had suffered considerably from extravagant engineering. No doubt this was true in isolated cases, but as a whole he thought they had derived very much benefit from moderate engineering, and he did not think a sweeping condemnation should be passed because in a few instances, perhaps, the wants of a town had been somewhat over-estimated, or the ambition of the engineer had somewhat exceeded the capacity of the pockets of his employers. On the other hand, what had been called "gossamer" construction had been deprecated. Mr. Hawksley had very well said that they ought not to put up gasholders of which they were in constant fear as to whether they were capable or not of resisting a gale; but between these two extremes there was a mean, and it was to this mean that they ought to endeavour to attain. In the pursuit of it he was strongly of opinion that Mr. Woodall had not overstated the case when expressing his belief that good works could be constructed at a cost of about £250 per million feet. He rather objected to an estimate of such a character being based on so much gas being made per annum; as, although, perhaps, if an average were struck, the estimate might be a fair one, yet for practical purposes it seemed to him that daily production should be taken as the basis of the estimate; and, going into the matter, he found that in ordinary times it did not seem at all impossible to come within Mr. Woodall's figures. The new works the members had visited at Windsor Street were in a sufficiently forward state to make an estimate of the probable cost, within a very small sum, and he was confident that these works would be completed in their entirety, without including the cost of land, at an expenditure not exceeding £30,000 per million cubic feet of gas manufactured per day. Now, if to this sum 50 per cent. were added for the cost of mains, services, and meters, there would be an expenditure at the rate of £45,000, which was somewhat under Mr. Woodall's estimate—at all events, he did not think the £50,000 need be exceeded in works of such a size as at Windsor Street. Mr. Woodall was very sanguine of the possibility of working with lessened storeage, and, in fact, of eventually doing away almost entirely with the necessity for gasholders; but he (the President) could not at all agree with him upon this point. He thought it would be found that the greater experience they had in the use of gas for heating purposes, the more gasholder room they would require. This had been his experience up to the present time. When he first came to Birmingham, where gas was more used for heating purposes than in any other place in the Kingdom, he had heard it said that because there was so much used in the daytime storeage was not so much required; but he very soon found out that not only was this not the case, but that it entailed a greater percentage of storeage, and the rule he laid down was that the minimum storeage should be equal to the maximum day and night consumption. This he had found to be a tolerably safe mode of working, and although they had been helped by the abolition of Sunday labour—for this was the means of diminishing the necessity for storeage, and not of increasing it—he was still of opinion that the proportion he laid down ought to be followed. With regard to public lighting, he could hardly expect the meeting to concur with what he had to say; b. he was strongly of opinion that the question of public lighting had not been looked upon by gas companies in exactly the right light. They appeared to think, because they were in the possession of a locality, that therefore every foot of gas must be paid for on the same terms. He did not think this was the principle upon which ordinary traders, subjected to competition, would have acted. He should have thought they would have consulted the wishes of the community, upon whom they really subsisted; that they would rather have been anxious to advertise their wares in the streets, than have exacted from the corporate bodies their full due. Had this principle been acted upon in London —where, he made bold to say, the public lighting, taken as a whole, was a disgrace to all concerned—he did not think they would have seen so much of the electric light. He considered that the reproach with regard to the public lighting of London ought to be shared partly by the companies and partly by the local authorities; but he did think that if the companies themselves had acted in a somewhat more liberal spirit, there would not have been that decided antagonism between the governing bodies and the companies themselves which had arisen. With regard to the charge of inconsistency which Mr. Woodall had made against Mr. Livesey, it was probably a fair argumentative retort, but he did not think the meeting would endorse it. Mr. Livesey had frankly said that the sliding scale had been an additional inducement to him, and he saw nothing to reproach him with on this score. They were always actuated by motives of self-interest, and it could not be expected that one should work entirely for the benefit of others. It was not the slightest reproach to Mr. Livesey, if it should be the case, that he was exercising more diligence and more perseverance because of the additional advantage offered by the sliding scale; but he (the President) was sure the meeting would entirely acquit Mr. Livesey of any inconsistency on this score.

[The length to which our report has this week extended, compels the holding over of the two remaining papers—Mr. Gandon's and Mr. Goddard's—with the discussions, till next week.]

NOTES FROM SCOTLAND.

(FROM OUR EDINBURGH CORRESPONDENT.)

EDINBURGH, *Saturday*.

In gas circles the question is now being asked—When are we to have all the reports of the Jurors appointed to examine the various articles shown at the exhibition in Glasgow nine months ago? No one has as yet answered the question in anything like a satisfactory way; and, indeed, it is a pretty general opinion that, as the Philosophical Society have been rather unfortunate heretofore in their efforts to gratify a very natural curiosity, there will be a proper and careful revision of the report upon gas-stoves before it is given to the public. No one, I am certain, has the slightest desire to force on the Committee to a hasty or rash conclusion, which might at some subsequent date require to be recalled; but nine months, in all conscience, is surely a sufficiently long-enough period for any body of gentlemen who know their business (and in this case no one would suggest a word to the contrary) to "inwardly digest" the facts and figures which have been the accumulated results of exhaustive experiments. I have it on pretty good authority that the report is ready, but that on account of the holiday season, or some other cause equally reasonable, the Jurors cannot be got to adhibit their signatures to the document. There may be a reason for this beyond anything that appears on the surface, and this may be gathered from the few statements I am now about to make. The report, I am given to understand, takes up, in a somewhat novel fashion, the question of the heating power of gas-stoves. It deals with preconceived notions as to the unit of heat in such a bold and uncompromising style, that it may not have a very soothing effect upon the minds of those engaged in the practical department of making stoves. But, however unpalatable the conclusions of the Jurors may be, it is really time the public should have possession of them. From the marked ability of the gentleman who has taken the lion's share of the trouble in connection with this report, I am sure he will vigorously defend his opinions against all comers; and I am also convinced that if once the report were submitted to the inspection of those interested in the matter, by its publication in the JOURNAL, a discussion would ensue which would do much either to remove or to confirm existing ideas as to the heat-giving and healthy or unhealthy (as the case may be) powers of all gas-stoves. It is only charitable to suppose that the Jurors, taken as a body, have a reason for the "faith that is in them" with respect to these stoves, although it may be that an innate modesty forbids its exhibition or publication. They are to be reminded, however, that the duty which they accepted when the exhibition opened has not yet been completely fulfilled, and if it is to be done at all "'twere well it were done quickly."

The condition of affairs at the Comrie Gas-Works does not appear to be very satisfactory. The accounts for the past year are not on the right side for the Shareholders, and, under the impression that a screw is loose somewhere, the Company, at a meeting held on the 25th ult.—Major M'Nab in the chair—unanimously agreed to remit to Mr. A. Napier, Manager of the Crieff Gaslight Company's works, with full powers to report upon the present state of the Company's affairs, the cause of the deficiency, and the condition of the plant, &c. Mr. Napier's report is to be ready in three weeks.

The Gas Corporation of Arbroath have this week agreed that the price of gas for the next year shall be 5s. per 1000 cubic feet, with a rebate of 2½d. per 1000, thus reducing the price by 2½d. as charged at present. The profits for the year ending the 31st of May last amount to £769 3s. 10d., being £7 13s. 2d. more than last year. The increase of profit is not much to boast of, but still it is an increase, and as such is satisfactory. According to the Act, one-half of the profits is handed to the Town Council for public improvements, and the other half is returned to the consumers in the shape of a rebate.

On Monday last the annual meeting of the Forres Gaslight Company was held in that town, under the Presidency of Mr. W. Raff, Chairman of the Company. The affairs of the Company are in such a good condition that the Directors have been able to declare a dividend equal to 7 per cent. on the share capital, and to carry forward a balance of over £70. A resolution in favour of adopting the report was unanimously carried. The price of gas continues at 7s. 11d. per 1000 cubic feet, subject to a discount of 10d. for cash.

The Pittenweem Gaslight Company have this week declared a dividend of 8 per cent., and continued the price of gas at 5s. 10d. per 1000 cubic feet.

The Edinburgh Town Council, at their usual meeting this week, have adopted the report of the Lighting and Cleaning Committee anent the electric light, and operations will be proceeded with immediately to have the necessary works executed so that North Bridge and Princes Street may be illuminated on the occasion of Her Majesty's visit, towards the end of August. Councillor Landale, as Convener of the Committee, moved the adoption of the report, and in doing so said that the electric light had now passed beyond the experimental stage, and, if possible, Edinburgh should do something to develop it. The report showed that there were two estimates—one for the use for three months of the appliances in connection with the electric light, and the other for fitting up the appliances permanently. No additional expense would be caused by the experiment in the event of the Council agreeing to adopt the light, as the cost of the trial would be deducted from the expense incurred in permanently fitting up the electric light.

Towards the end of last week the Local Authority of Elie had under consideration the report of Messrs. Little and Boothby, the Engineers appointed to inspect the district with a view to obtain a water supply. These gentlemen have visited various spots, but they consider the Dreel Burn the most suitable, and they have given probable estimates of the cost of schemes for supplying St. Monan's, Elie, and Earlsferry with a joint scheme, and also for supplying Elie and Earlsferry alone. The joint scheme is estimated to cost 1s. 3d. per £1 of rental, or one-half of the statutory rate. A deputation has been appointed to wait on the proprietors of the Dreel Burn and adjacent lands to ascertain terms of purchase, &c.

In consequence of a feeling that the supply of water in Kinross—mainly derived from wells—is not so pure as it ought to be, representations have been made to the Board of Supervision, who have set the proper machinery in motion to compel the Local Authority to provide an adequate supply of wholesome water. But the people of the town, or a number of them, at any rate, thinking that the wells are quite sufficient for present purposes, met in the Town Hall this week, and carried a series of resolutions to the effect that a projected water scheme from the Ochil Hills was unnecessary and inexpedient; that the present wells, if cleaned, deepened, and protected from surface pollution, are quite sufficient for the town; and that a memorial be forwarded to the Board of Supervision praying the Board to suspend proceedings in enforcing any unnecessary water scheme upon the inhabitants until an analysis has been made of the water, after the wells have been thoroughly cleaned out.

At a public meeting of the inhabitants of Penicuik on Tuesday evening, it was unanimously agreed to prosecute a scheme whereby an additional supply of water will be obtained for the town. Lying as the town does almost under the very shadow of the Pentland Hills, there is yet an abundance of springs, which, if not capable of collection or of supplying a populous place, are numerous enough to afford a valuable addition to any existing scheme. The present supply to Penicuik comes from the Siller (*i.e.*, silver) Burn, which has its rise at the foot of the Pentlands, and the water of which was granted at a nominal cost by the late Sir George Clerk. Then the cost of introducing the water was borne by a legacy left by the late Mr. A. Cowan. The supply has now proved inadequate, and the result of inquiries which have recently been conducted is that an additional supply can be obtained from Salter Skye, about half a mile from the Siller Burn, at a cost of something like £2500, being equal to a rate of 4d. or 5d. in the pound. The meeting, after having been addressed by several gentlemen, unanimously resolved to proceed with the scheme.

A few weeks ago I directed attention to the condition of the finances of the Dundee Water Commissioners. On Thursday the subject was under the consideration of the Commission. Prior to the meeting, a joint meeting of the Water and Police Commission was held, and after a long conference it was agreed that the latter should pay £2300, or about £1300 more than at present, which represents ½d. per £1 of assessment on the police-rates, and a relief to the extent of 1d. per £1 to the payers of the domestic water-rate. At the meeting of the Water Commission held afterwards, the estimates were considered and approved. The expenditure this year included £1908 of deficiency from last year, £14,315 of annuities, £17,150 of interest, £3377 of sinking fund. The total estimated expenditure was £43,879 1s. The total estimated revenue—the domestic water-rate being taken at 1s. 6d. per £1, as against 1s. 4d. last year—was £43,617 10s., showing a deficiency of £261 11s. The estimates were approved, and the assessment for the year fixed at 1s. 6d. per £1 on the domestic ratepayers, and the public rate at 1d. A feeling was expressed that steps should be taken to fund the debt of the Water Commission, and it was stated that if it could be taken up at 3½ per cent., a great relief would be secured to the ratepayers.

(FROM OUR GLASGOW CORRESPONDENT.)

GLASGOW, *Saturday*.

The death has just been announced of Mr. James William Miller, who was for many years Chairman of the Oban Gas Company. Mr. Miller, although only in his 39th year, was one of the best known and most influential men in the West Highlands. He was as highly respected as he was widely known.

It may be worth while to give, by way of supplement to Mr. West Watson's figures on the Glasgow gas supply, quoted in last week's issue of the JOURNAL, the returns for the year ending May 31, 1881. The year's make of gas in Glasgow at the three stations was as follows:—

Dalmarnock works	838,849,000 cubic feet.
Dawsholm works	593,750,000 ,,
Tradeston works	534,323,000 ,,
Total	1,966,922,000 cubic feet,

being an increase of 107,340,000 cubic feet over the production in the year 1879-80. The quantity of coal carbonized during the year was 199,266 tons, of which nearly one-fourth consisted of Lesmahagow and other first-class qualities.

I am in a position to say that the arrangements for the forthcoming meeting of the North British Association of Gas Managers, which is to be held in Glasgow, are now practically complete. The meeting will open on Thursday, the 21st inst., and will extend over part of the following day, the sittings taking place in the large theatre of the Philosophical Society's new buildings in Bath Street, under the presidency of Mr. James M'Gilchrist, of the Corporation Gas-Works, Dumbarton. It is gratifying to know that, in addition to the Presidential address, there is promise of an abundance of interesting and valuable papers; indeed, I believe that the programme of business will include the titles of not fewer than eight papers. I may indicate two or three of the subjects that are likely to be brought forward. Mr. Malam, of the Dumfries Corporation Gas-Works, has lately devised and patented some modification of the process of carbonizing with which his name was very prominently identified some six or seven years ago; and it is expected that an account of the process as it now stands, together with some of the results, will be made the subject of a communication to the meeting. Some facts in connection with the treatment of the residual products of gas manufacture will be detailed and experimentally illustrated by an Arbroath chemist; and there is a paper to be read, I understand, by Mr. Wilson, of Middlesbrough, on the applicability of his mode of using gaseous fuel in heating retorts. The annual dinner of the Association will take place in the Grand Hotel, Charing Cross, Sauchiehall Street. Altogether, a highly interesting meeting is confidently expected.

The workmen and other persons connected with the Corporation Gas-Works, Inchgreen, Greenock, held a meeting last Monday, in the office at the works, for the purpose of presenting Mr. A. G. Quigley with a token of their regard on the occasion of his leaving the works to fill the situation of Manager at Penicuik Gas-Works. Mr. Maitland presided, and in a neat speech, conveying the best wishes of all present, in the name of the workmen, presented Mr. Quigley with a purse of sovereigns. Mr. Quigley made a suitable reply, and the proceedings were shortly afterwards brought to a close.

The annual general meeting of the Hawick Gaslight Company was held in the Town Hall yesterday—Mr. John Melrose, Chairman, presiding. There was a good attendance. The leading facts of the report have already been mentioned in my "Notes." After the report was passed, the meeting agreed, on the motion of the Chairman, that the total loss which will be occasioned by the contemplated removal of the Company's works to Mansfield Park should be written off out of the profits of the Company, by equal instalments, spread over ten years; and in another motion the Directors were authorized to proceed at once with the erection of the new works, according to the plans which were exhibited at the meeting. Afterwards the vacancies in the directorate were filled. Mr. J. Glenny was elected in the room of Mr. Walter Laing, Mr. G. Tait was re-elected, Bailie Inglis was re-elected to represent the Town Council, and Provost Watson was continued a Director in his own right.

Business was done last Saturday, and again on Wednesday, in Glasgow Corporation 9 per Cent. Gas Annuities, at £230.

At the Hamilton Small Debt Court yesterday William Robertson, miner, sued the Corporation of Hamilton, as the Gas Commissioners, and Mr. Strang, as proprietor of the premises in Lamb Street, for £12 in name of damages in consequence of an explosion of gas which took place on the premises in the month of June last year. After proof had been led by the pursuer and the Corporation, the Sheriff, without calling on defenders' agents to reply, dismissed the case, holding that the pursuer had failed to prove negligence on the part of either of the defenders.

The Lockerbie Police Commissioners lately issued voting cards with the view of learning the opinions of the ratepayers in regard to the proposal to obtain a supply of water by gravitation from Foulraw Burn, Tundergarth. Cards were issued to 410 ratepayers, but only 185 of them were returned, with the following results:—Against the scheme, 100; for, 85; majority against, 15.

At the last meeting of the Greenock Water Trust it was stated that the total cost of the Loch Thom extension works up to the 11th of June, 1881, had reached £16,870 17s. 7d.; and from the statement of the revenue and expenditure for the past year it was shown that the former amounted to £23,866 19s. 1d., and the expenditure to £23,857 8s. 10d., leaving a surplus of £9 10s. 3d.; but it was stated by Bailie Leitch that sums, amounting to at least £800, had been paid during the year by the Trust that were not likely to fall upon it again. Although the revenue was only £9 in excess of the expenditure, as shown in the accounts, it was actually £1000 more than was estimated at the commencement of the year.

The week opened firm in the Glasgow pig iron market, but comparatively little business was done during most of the week, and the prices were almost stagnant for three or four days. The close on Friday afternoon was—sellers at 46s. 10d. cash and 46s. 11½d. one month, and buyers offering ½d. per ton less.

No change of any importance can be reported in the coal trade, either in respect of demand or prices.

CURRENT SALES OF GAS PRODUCTS.

MANCHESTER, *June* 30, 1881.

Tar, about 40s. per ton at the works.
Ammonia liquor (sp. gr. 1·03), 24s. to 25s. per ton.
,, sulphate (white), £20 5s. per ton, firmer.
,, ,, (grey), £19 12s. 6d. to £19 17s. 6d. per ton.
Ammonia muriate (white), £30 to £31 per ton.
,, ,, (brown), £25 to £27 per ton.
Muriatic acid, about £1 10s. per ton.
Sulphuric acid (brown vitriol), £2 17s. 6d. per ton—no change.

MR. VINCENT HUGHES, who has been for some time past Assistant to Mr. A. C. Fraser, the Engineer and Manager of the Bolton Corporation Gas-Works, has just received an appointment in connection with the gas-works in course of erection at Tipton.

PRESENTATION TO MR. W. CALLOW, OF BIRKENHEAD.—On the 13th ult. the *employés* of the Gas and Water Departments of the Corporation of Birkenhead met together at the gas and water offices for the purpose of presenting a testimonial to Mr. W. Callow, on the occasion of his retiring from the office so ably held by him for a period of 29 years. The presentation consisted of a beautifully illuminated address and a handsome timepiece, together with mantel ornaments, &c. Mr. H. Rawcliffe, J.P., Chairman of the Committee, presided on the occasion, and expressed his pleasure at being the medium, on the part of the *employés*, of presenting to Mr. Callow a testimonial to which he was so much entitled. Mr. T. S. Deakin, Deputy-Chairman, also spoke in eulogistic terms of the services rendered to the Corporation by Mr. Callow. Several of the officials then gave expression to the kindly feelings they entertained for Mr. Callow; and after his health had been drunk in a hearty manner, the meeting broke up.

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